18 October 2016

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By online submission

Dear Mr Pierce

Submission to Consultation Paper: National Electricity Amendment (Emergency under/over-frequency control schemes) Rule 2016

The Australian Energy Market Operator (AEMO) welcomes the opportunity to contribute to the AEMC's consultation process for Rule proposals on emergency frequency control schemes lodged by the Minister for Mineral Resources and Energy (South Australia).

If you would like to discuss this submission further, please don't hesitate to contact me.

Yours sincerely,

David Swift
Executive General Manager – Corporate Development

Attachments: AEMO SUBMISSION - AEMC CONSULTATION PAPER FINAL.DOCX

Attachment: AEMO Submission in response to AEMC Consultation Paper-

National Electricity Amendment (Emergency under-frequency control schemes) Rule 2016

and

National Electricity Amendment (Emergency over-frequency control schemes) Rule 2016

This submission adopts the same abbreviations and definitions used in the AEMC's Consultation Paper.

Executive Summary

In this submission AEMO:

- provides context and suggestions to progress the issues raised in the Consultation Paper relating to UFLS/OFGS schemes;
- supports establishment of a framework for the declaration of specific 'non-credible contingency events' for which pre-emptive action can be taken to contain the consequence of the event(s) to an acceptable and well defined level; and
- responds to questions raised by the AEMC in the Consultation Paper.

AEMO has observed that as the mix of generation supplying electricity to consumers has changed over time, an increasing number of the expectations set out in the FOS may no longer be met in some circumstances because they are not supported by clear provisions in the NER in relation to:

i. The regulatory framework governing the design, operation and funding of under and over frequency emergency control schemes - including the review and upgrade of these schemes. These mechanisms are the last line of defence in addressing the impacts of contingency events and may now not be sufficient to prevent system shutdown in some circumstances.
ii. Management of non-credible events.

To address issues raised in the AEMC's Consultation Paper, AEMO proposes in this submission a series of measures that are considered economically efficient and consistent with the long term interests of consumers in terms of price, quality, safety and security of supply to address the issues raised in the AEMC's Consultation Paper. While it would not be efficient or even practical to take action to mitigate all non-credible contingencies, it is expected that it would be in the best interests of customers to address the potential high impacts of some of these events. Where risks warrant managing, appropriately designed under and over frequency emergency control schemes are likely to represent a proportionate response.

UFLS schemes

As trends of increased penetration of DER (such as rooftop PV) and reduced online synchronous inertia continue in other regions, UFLS schemes across the NEM will need to be redesigned. While the effectiveness of the existing schemes across the NEM are being challenged, the most critical and immediate needs are in South Australia. It is now apparent that under certain circumstances, SA is exposed to system conditions where non-credible loss of the Heywood interconnector (when importing into SA) could result in a Rate of Change of Frequency (RoCoF) that is beyond the capability of the existing UFLS scheme in SA to respond. To effectively contain the effects of high RoCoF events, it is necessary to replace the existing UFLS scheme with an adaptive UFLS scheme, which can respond much more rapidly to an interconnector trip that results in high RoCoF. Such a scheme would use high speed communication and detection systems, in conjunction with sophisticated supervisory control to allow sufficient load to be shed in much shorter timeframes than the current scheme.

Changes to the existing UFLS infrastructure will need to be supported by clearly defined responsibilities in the NER for design, operation and funding. The current Rules do not appear to meet this need, however AEMO suggests that a suitable framework could be readily developed within the scope of the two Rule proposals that this submission responds to.

Properly designed UFLS schemes are a relatively low cost mechanism that can significantly enhance safety, reliability and security of supply in the NEM. As such, updating NER frameworks to support deployment of improved UFLS schemes provides an economically efficient means of advancing the NEO.

OFGS schemes

AEMO broadly supports the case presented in section 3.1.3 of the Consultation Paper for a formal framework in the NER for implementation of OFGS schemes. The same system characteristics that can cause frequency to decrease if supply to a region is suddenly reduced can cause frequency to increase when load is suddenly reduced. The loss of an interconnector while exporting from the region is an example where this could occur. Just as it is important to establish a suitable NER framework for under frequency event management across the NEM, so to should provisions be in place to support management of over frequency events. Following more severe, non-credible faults in these circumstances the positive RoCoF can be high.

Clear roles and responsibilities for AEMO, NSPs and *market participants* in the development and implementation of OFGS schemes would be of significant benefit in mitigating the risks of these events.

Protected events

The NER and FOS are currently unclear in relation to the '*multiple contingency events'* and non-credible contingency events that emergency frequency control schemes should be designed to mitigate. With the exception of specific UFLS and other limited measures provided for in Chapter 4 of the Rules, AEMO's power system security responsibilities generally do not extend to ensuring the system will remain in a satisfactory operating state following multiple or non-credible contingency events.

The NEM cannot be operated economically to be resilient to all potential non-credible contingency events, most of which are extremely unlikely to occur. No power system in the world is run in this manner. If the network was required to be operated like this virtually all major transmission and distribution infrastructure would need to be duplicated at unacceptably high costs to consumers to create the necessary redundancy to address impacts of these very low probability events,. While protecting against all such events would be uneconomic and impractical, power system security would be reinforced through identification of certain non-credible contingency events where the probability of occurrence and potential impacts should the contingency occur mean it is cost effective to take action to mitigate.

To provide a clear path for managing high RoCoF from non-credible contingency events, the NER require amendment. One approach would be to introduce a flexible intermediate category of events that would sit in between credible and non-credible contingencies in terms of likelihood of occurrence. This category of events- notionally referred to as '*protected events*' – would comprise some *non-credible contingency events* (under the current NER definition) for which AEMO would be authorised to take some defined level of pre-emptive action in order to contain prospective impacts of the event within a prescribed level (for example, not more than 60% of load shed in a region). We propose that the Reliability Panel would be the most appropriate body to determine the events or circumstances that qualify as protected events.

This would be a significant modification to current obligations to maintain the power system in a secure operating state solely against the risk of credible contingencies. A protected events mechanism could be designed to link with OFGS and UFLS schemes by requiring AEMO and other parties to operate the power system within the capability of such schemes. As the capability of UFLS and OFGS schemes progressively develops, there is potential for less intrusion in the market to be required. The framework needs to be designed in a manner which ensures any costs imposed are efficient and necessary to provide an acceptable level of security.

In addition to providing a clearer basis for management of extreme frequency conditions that may result from particular non-credible contingency events, the protected events framework provides a flexible mechanism for management of additional power system conditions that may emerge as the generation mix in the NEM continues to change, without the need for further changes to the NER.

The NER should include a clear governance framework to guide the Reliability Panel on the principles and process that it should apply when it determines that a non-credible contingency event is a protected event.

Protected events should also be accommodated within the broader transmission planning framework to ensure that any cost effective opportunities to reduce risk are acted upon.

1. Considerations to inform development of this Rule change proposal

AEMO appreciates the opportunity to provide some further context on the role and operation of emergency frequency control schemes in the NEM and the treatment of contingency events in the NER.

In this section, AEMO presents its views on the key concepts discussed in the AEMC Consultation Paper.

1.1. Under Frequency Load Shedding Schemes

UFLS schemes are used in most interconnected and standalone power systems around the world to address the impacts of significant under-frequency events. UFLS schemes operate to address sudden and unexpected interruptions to the supply-demand balance of a power system that may otherwise result in a blackout of subsections of a power system or an entire interconnected system. The UFLS scheme in the NEM is designed to operate both as a NEM-wide scheme to mitigate impacts of inter-regional supply disturbances and as a single-region scheme where the imbalance only affects a single part of the NEM[1].

Issues affecting existing SA UFLS scheme

As detailed in section 3.1 of the Consultation Paper, there are a number of region-specific factors affecting operational efficacy of the existing UFLS scheme in SA.

The most significant of these factors is the increased potential for high RoCoF conditions in SA following upgrade of the Heywood interconnector and closure of Northern Power Station[2]. The settings for the UFLS scheme are reviewed by AEMO every two years, to ensure that design of the scheme continues to meet the needs of each region in stabilising the power system against significant frequency deviations[3] .

The NEM mainland *Frequency Operating Standards* (FOS) define the range of allowable frequencies for the power system during and following a contingency event. Load shedding in the NEM is designed to automatically trigger if system frequency deviates beyond the allowable range in the FOS.

It is now apparent that under certain circumstances SA is exposed to system conditions where high RoCoF following a non-credible loss of the Heywood interconnector (when importing into SA) would cause system frequency in the islanded SA region to decline at

[1] Clause 4.3.1 (k)(2) suggests the objective of load shedding is "to arrest the impacts of a range of significant multiple *contingency events* (affecting up to 60% of the total *power system load*) to allow a prompt restoration or recovery of *power system security*, taking into account under-*frequency* initiated *load shedding* capability provided under *connection agreements* or otherwise".

[2] Refer to pages 22-24 of AEMO's *Future Power System Security Program- Progress Report- August 2016* and section 3.1.1 if the Consultation Paper for further details.

[3] As noted in the Consultation Paper, load shedding can occur in response to certain *credible contingency events* in SA if the region is islanded from the rest of the NEM, due to the broader frequency operating band in effect in SA for *separation* events (as defined in the FOS).

such a rate that the existing fixed UFLS scheme would be unable to act quickly enough to arrest the frequency decline, leading to a potential black system event.

The mode of operation of most UFLS schemes is relatively simple - if there is an unexpected reduction in frequency, load will be progressively shed from the power system in an attempt to restore the supply-demand equilibrium. To date, in the mainland regions of the NEM, this has been accomplished through the use of automatically acting, pre-programmed frequency-sensing relays. If generation is lost unexpectedly power system frequency will decrease, and the UFLS scheme will automatically trip specific load blocks at particular frequency thresholds that are outside the nominal operating band [4] in a pre-defined sequence with time delays between successive load blocks. In this way, UFLS schemes act to assist recovery of system frequency into the *normal operating frequency band* following a contingency event (i.e. an under frequency event), while minimising the risk of additional uncontrolled loss of generation.

The existing UFLS scheme operates as a '*fixed*' scheme, and is unable to act quickly enough under some circumstances to maintain system frequency. The characteristics of *fixed* and *adaptive* UFLS schemes are discussed in greater detail in section 2.3 of this submission.

AEMO is of the view that a Special Protection Scheme (SPS)[5] could be designed to operate as part of an adaptive UFLS scheme in SA to address the unexpected loss of the Heywood interconnector. An SPS of this kind would be able to shed load in SA directly based on a signal indicating that both circuits of the Heywood interconnector were open. This approach allows action to be taken to arrest the drop in system frequency by directly detecting the event and shedding load, without waiting for system frequency to fall before acting (in the case of a traditional fixed UFLS scheme).

If an adaptive scheme with an SPS to address the sudden loss of the Heywood interconnector can be designed and implemented in SA, it would allow load to be shed in response to contingency event(s) significantly faster than the existing fixed scheme. This may require the establishment of dedicated communications infrastructure and development of load shedding procedures that would respond directly to system events such as the loss of both circuits of the Heywood interconnector, rather than triggering on the basis of power system frequency.

Points for clarification- under frequency event management

The existing NER framework for management of under frequency events would benefit from a less prescriptive description of the load shedding mechanism, as well as clarification of roles and responsibilities to support development, implementation and on-going operation of adaptive UFLS schemes. Currently, responsibility for design, approval, funding, investment, development of settings, and maintenance are all unclear or unspecified under the current framework.   The development of flexible, fast acting adaptive UFLS schemes/Special Protection Schemes, will be necessary in regions susceptible to high levels of RoCoF, and this is unlikely to be possible in the absence of a clear NER framework.

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[4] Refer to the *normal operating frequency excursion band* defined in the Frequency Operating Standards

[5] Similar to what exists in Tasmania to cover the loss of Basslink

AEMO considers this could be achieved by amendments to the existing NER including:

- Confirming the objectives of load shedding schemes, including clarification of which '*multiple contingency events'* and *non-credible contingency events* they should be designed to mitigate (see section 1.3 of this submission for further discussion on this point).
- Clarifying roles of AEMO and NSPs[6] in designing, reviewing and implementing load shedding schemes, to give consideration to the to the expanded roles required of parties to support adaptive load shedding schemes.[7]
- Generalising the description of load shedding schemes so the NER are not prescriptive as to how they can be operated and at what particular frequency range they may be expected to trigger.[8]
- Defining clear, timely and economically efficient mechanisms for NSPs to recover costs for implementation and on-going operation and maintenance of network and communications infrastructure to allow operation of adaptive load shedding schemes.

1.2. Over Frequency Generation Shedding Schemes

AEMO supports the establishment of a formal framework in the NER for implementation of OFGS schemes.

AEMO has undertaken preliminary design work for an OFGS scheme for SA, and is in the process of discussing implementation of the scheme with SA NSPs and generators[9]. These works have progressed to date on the basis of mutual goodwill and recognition of shared interests between AEMO, NSPs and SA market participants. However, these works are still in train and may not be implemented in a timely way without established NER framework for OFGS schemes.

AEMO notes that an OFGS scheme is in operation in Tasmania as one of the mechanisms to address the potential impacts of an over-frequency event resulting from the loss of Basslink (a credible contingency event), however this example is not directly comparable to arrangements under consideration to mitigate impacts resulting from the potential loss of both circuits of the Heywood interconnector (a non-credible contingency event).

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[6]For instance, clarifying who has primary responsibility to design and assess fit-for-purpose of emergency frequency controls as detailed in 4.3.1(k), and S5.1.10.1

[7] For instance, clarifying responsibilities of NSPs and Registered Participants in clause S5.1.8 to 'consider *non-credible contingency events'* in network planning in the context of requirements for AEMO under clause 4.3.1 (k) for the purpose of an adaptive load shedding scheme

[8] For instance, remove references such as 'initiated automatically by frequency' from clause 4.2.6 (c) and '*Market Customers* must provide their *interruptible load* in manageable blocks spread over a number of steps within under-*frequency* bands from 49.0 Hz down to 47.0 Hz' from clause 4.3.5 (b).

[9] Refer to page 33 of AEMO's *Future Power System Security Program- Progress Report- August 2016*

The system behaviour affecting operational efficacy of the existing UFLS scheme in SA when the Heywood interconnector is importing into SA (as described in section 1.1 of this submission) gives rise to the need for implementation of an OFGS scheme for circumstances when SA is exporting through the interconnector. High RoCoF following prospective non-credible loss of the Heywood interconnector under export conditions has the potential to cause system frequency to increase in the islanded SA region such that the risk of uncontrolled cascading trip of SA generators leading to a subsequent under-frequency event is material. The utility of such a scheme has been emphasised in recent work by AEMO and ElectraNet[10].

Clear guidance in the Rules on obligations, roles and responsibilities for AEMO, NSPs and *market participants* in development and implementation of OFGS schemes would be of significant benefit in expediting implementation of an OFGS for SA as well as in other regions if the need emerges.

Points for clarification- over frequency event management

There is currently no regulatory framework in the NER for OFGS schemes. A workable NER framework for OFGS might require the following support from the Rules:

- A clear statement of the objectives of over frequency schemes, including clarification of the type of '*multiple contingency events'* and *non-credible contingency events* they should be designed to mitigate (see section 1.3 for further discussion on this point).
- Clear roles and responsibilities for all involved parties, including generators, AEMO and NSPs in designing, reviewing, implementing and maintaining OFGS schemes.
- Clarification of obligations for new and existing market participants or NSPs to install relay/communications equipment to support the orderly and coordinated trip of generation if that is required to meet the objectives. This provision should not be prescriptive, allowing generation to be shed through either a direct signal to trip from supervisory controls, through the use of fixed frequency trip points, or other controlled reduction in power output as appropriate to the area and region within which they are located.

1.3. The case for a new category of 'protected events'

The Rules contain multiple different obligations and responsibilities for AEMO and NSPs to plan for or operate the power system before and after contingency events, including the use of under-frequency load shedding schemes. These clauses variously refer to requirements in relation to 'multiple *contingency events*'[11], '*non-credible contingency events*'[12] and '*significant* multiple *contingency events*'[13]. Ostensibly, this terminology may or may not refer to the same

[10] Refer to pages 3-4 of Update to renewable energy integration in South Australia

[11] NER 4.3.1(k), and S5.1.10.1

[12] NER S5.1.8

[13] NER 4.2.6(c)

events or class of events and does not specifically identify *which* events are to be considered in the design basis of emergency frequency control schemes.

Further to this, Part B of the FOS- which provides critical guidance to AEMO and NSPs for power system security obligations- uses the terms '*multiple contingency event'* and '*separation event'*, and defines them as follows:

- Separation event: means a *credible contingency event* in relation to a *transmission element* that forms an island.
- Multiple contingency event: means either a *contingency event* other than a *credible contingency event*, a sequence of *credible contingency events* within a period of 5 minutes, or a further *separation event* in an island[14].

These terms do not correspond exactly to Rules definitions for non-credible contingency events and credible contingency events. This results in confusion as to which kinds of events should be considered as 'multiple *contingency events'* under the FOS and how to reconcile the FOS expectations with Rules obligations for AEMO and NSPs relating to power system security and network performance.

Part B (f) of the FOS suggest that power system frequency as a result of multiple contingency events should be maintained within the extreme frequency tolerance limits. However, in accordance with the power system security principles, the power system is not planned or operated such that frequency can be maintained following **all** possible contingency events.

The FOS reflect an intent that power system frequency be maintained within the parameters set out in the FOS for some (or possibly all) non-credible contingency events, but there is no guidance as to whether, and in what circumstances, AEMO should take measures in advance of such events occurring, or only following their occurrence. In conjunction with the Rules, it appears that only the existing UFLS framework is available to AEMO as a pre-emptive measure to meet this frequency standard.

These uncertainties need to be clarified to facilitate the implementation of efficient measures to address risk appropriately as the power system environment changes. One approach would be to introduce a flexible intermediate category of events in the Rules that would sit in between credible and non-credible contingencies. This category of events - notionally referred to as '*protected events*' – would comprise non-credible contingency events (under the current Rules definition) for which AEMO would be authorised to take pre-emptive action to contain the prospective impacts of the event within a prescribed level (for example, not more than 60% of load shed in a region).

The introduction of protected events would allow AEMO a range of options to act pre-emptively to address the impacts of what would otherwise be a non-credible contingency event. Under the existing NER framework, the power system must return to a *secure operating state* following all credible contingency events while minimising the use of controlled load shedding. The establishment of a new category of protected events would

[14] An additional definition for *multiple contingency events* is provided for the purpose of incident report in relation to NER clause 4.8.15(a)(1)(ii) has been provided by the Reliability Panel.

allow the use of controlled load shedding - along with other approved mechanisms that could be used pre-emptively - to avoid the impacts of a full or significant partial black system condition in a NEM region.

In the case of issues affecting operation of emergency frequency control schemes in SA, it would take some time to design, procure and implement a faster-acting adaptive system of emergency frequency controls. The protected events mechanism could be used in the absence of an effective control scheme to allow AEMO to act pre-emptively to operate the power system in such a way that potential non-credible loss of the Heywood Interconnector would not result in a system black event for the SA region. This could be achieved through the use of a least cost combination of measures as approved by a suitably qualified independent body (we propose the Reliability Panel), such as interconnector constraints, NSCAS arrangements or other system constraints to maintain RoCoF potential to within a limit within the *technical envelope* of the power system.

<u>Protected events- a strawman framework</u>

Existing obligations for maintaining power system security would be expanded by the introduction of additional rules for management of ‘multiple *contingency events'*/non-credible contingency events, whereby some events (notionally *protected events*) require action from AEMO or other parties. It is proposed that the protected events category would:

- Be flexible and allow the Reliability Panel to determine that **an event or class of events** should be ‘*protected*’, subject to appropriate cost benefit assessment (for each event) and ratification from an appropriate oversight body (such as the AEMC). Cost-benefit assessment could be undertaken by periodically considering advice from AEMO and other parties on measures available to appropriately mitigate the impacts of a protected event. It is proposed that the register of protected events would initially be empty.
- Define avenues open to AEMO and NSPs for management of protected events (e.g. use of dynamic system constraints), in a manner such that alternative lower cost mechanisms can be used if they become available in the future, without requiring further amendments to the Rules.
- Harmonise/clarify the responsibilities of AEMO and NSPs to develop systems and act in case of a protected event.

Given the large potential costs involved, protected events should be supported by a clear governance framework. When deciding whether an event or class of event qualifies as a protected event, and the standard to be met if the event occurs, the Reliability Panel’s decision should reflect the trade-offs between:

- the likelihood and consequences of the protected event occurring; and
- the costs (including market impacts) that arise when the power system is operated in order to mitigate the risk of a protected event.

Given the complexity and significance of the Reliability Panel’s decisions in this area, the Commission may wish to develop a process and criteria to guide the Reliability Panel in the exercise of its functions. This approach would seek to promote an efficient balancing of the system security benefits and the costs associated with taking pre-emptive operational measures.

The decision-making process should be robust and open, but also permit decisions to be fast-tracked in appropriate circumstances consistent with the NEO.

Protected events should also be accommodated within the broader transmission planning framework to ensure that any cost effective opportunities to reduce risk are acted upon. Protected events are likely to be low probability, high impact events. Emergency load shedding schemes are often most efficient means of maintaining system security when a protected event occurs since the cost of constructing the network in a fashion that avoids the risk can be extremely high.

However, in some cases there are cost effective actions that can be taken in order to reduce the risk of the event occurring, or even to remove the risk. For instance, there may be scope for the TNSP to reduce the risk that the protected event occurs by:

- reconfiguring its network,
- undertaking an investment, or
- acquiring network support and control ancillary services (NSCAS) or non-market ancillary services (NMAS) contracts.

The transmission planning framework should require TNSPs to plan their networks in a way that takes account of the costs to customers associated with emergency load shedding, and ensure that the network is designed to reduce risks to system security where the associated costs are proportionate.

2. Responses to Consultation Paper Questions

In this section we respond to questions raised in the Consultation Paper.

2.1. Question 1- Materiality of issues impacting management of extreme frequency events

Q1a Are the issues identified by the proponent likely to have a material impact on the NEM, over the medium to longer term?

The issues identified by the SA Minister as driving the need for this Rule change proposal are:

- increased penetration of DER in the NEM; and
- increased potential for high RoCoF conditions following contingency events (i.e. both under and over frequency events), as a result of reductions in synchronous inertia.

These issues will have a material impact on the NEM over the short, medium and long-term and are being considered as part of AEMO's *Future Power System Security* program.

AEMO expects that efforts to meet Australia's 2030 emissions reduction target of 26-28% from 2005 levels by 2030, in conjunction with renewable energy policies in place or under consideration at state and local government level, will drive further displacement of synchronous generation in all NEM regions by DER and large-scale asynchronous generation.It is AEMO's view that the trend of reduced levels of synchronous generation will continue in all NEM regions into the foreseeable future.

2.2. Question 2- Ability of the current frameworks to deliver effective emergency frequency control schemes

Q2a Do current frameworks, including currently allocated responsibilities of different parties, allow for the effective consideration of all physical solutions to extreme frequency events?

Current frameworks do not provide sufficient clarity on roles/responsibilities of parties, and do not include clear or adequate provision for effective consideration of physical solutions to extreme frequency events (i.e. both under and over frequency events).

Examples of where further clarity would assist consideration, design and implementation of effective physical solutions to emergency frequency controls are provided in section 1.3 of this submission.

2.3. Question 3- Potential changes to emergency frequency control schemes

Q3a Do current NER frameworks already allow for, actively prevent, or fail to account for, new technologies that could be used to provide more effective emergency frequency control schemes? How would these new technologies work and what kind of solutions can they provide?

Amendments to the NER are required to allow load shedding schemes to trigger on conditions other than system frequency and may need to operate using a different sequence of load blocks based on the state of the power system at any given time.

In general, UFLS can be divided into two categories - '*Fixed'* and *'Adaptive'* schemes.

‘Fixed’ UFLS schemes

‘*Fixed*’ schemes use an established technology that in most instances, is designed to shed the same series of load blocks at specific values of system frequency outside the *normal operating frequency band* in a set sequence based on assumed amount of load under the control of each relay in the network.

These schemes can be thought of as having one set of settings to handle all potential system conditions, and automatically act to progressively shed additional load until power system frequency stops falling to lower levels, or all load blocks are exhausted. Consistent with common industry practice around the world, the current NEM-wide UFLS scheme operates as a fixed scheme, where relay settings have been developed to mitigate the impacts of a multi-regional supply disturbance (i.e. a contingency event where multiple regions could be affected and ‘islanding’ may occur) so as to equitably spread load shedding between interconnected NEM regions to arrest the frequency drop. Design of a fixed UFLS scheme must consider a variety of factors that are unique to each power system, including the size of load blocks, the sequence and frequency trip point of each load block, the generation mix expected at time of operation (including the availability of synchronous inertia) and the contingency event size and type that the scheme is being designed to mitigate.

Because of the static character of the scheme, the same relay settings used for an inter-regional supply disruption must also be used to mitigate the impacts on frequency of a contingency event within a given region, regardless of time of day or the current state of the regional power system.

Fixed schemes typically trigger relay operation on the basis of frequency conditions alone; either automatically acting when system frequency passes predefined thresholds, or when RoCoF exceeds a design level as detected at each relay. In this type of scheme, larger disturbances are managed through shedding additional load blocks if system frequency does not adequately recover following shedding of the initial tranches of load.

‘*Adaptive*’ UFLS schemes

‘*Adaptive*’ schemes are a more technologically advanced means of managing frequency events. They leverage significant advances in communications and control technology in recent years to provide improvements in speed and flexibility of operation. Adaptive schemes operate for a given contingency event by dynamically determining the amount of load required to be shed to arrest the prospective frequency deviation, and shedding the load as soon as possible to restore balance between supply and demand. This is achieved through utilisation of a centralised supervisory control system to dynamically reprogram frequency-sensing relays on a continuous basis[15] in timeframes significantly less than a 5 minute dispatch interval. The ability to sense the current state of the power system allows adaptive schemes to optimise the amount of load shed to address the frequency impacts of contingency events. Because they use information characterising the current state of the

[15] Adaptive schemes are able to calculate optimised load shedding sequences and update relay settings every few seconds

power system, adaptive schemes are able to respond to the specific nature of a potential supply-demand disturbance, including:

- the size of the disturbance
- the RoCoF that would result from the disturbance
- the time available to recover system frequency while staying within the parameters of the FOS
- the appropriate amount and sequence of load to be shed in order to maintain system frequency within the bounds of the FOS.

An adaptive scheme is not limited to operating on the basis of frequency alone, but can be designed to trigger response based on frequency conditions, voltage conditions, system events such as operation of circuit breakers[16], or a combination of those things. Because of their dynamic nature, adaptive schemes do not require the use of inherent assumptions about availability of load, inertia or the nature of the contingency affecting a network, and can to respond in a variable fashion to different contingency events based on the design of supervisory controls.

Conclusions

Fixed and adaptive schemes both operate using the withdrawal of load to stabilise the power system following an unexpected disturbance, yet have fundamentally different capabilities. Adaptive schemes are able to:

- Operate with much greater precision than fixed schemes by programming relays based on the state of the power system immediately prior to a contingency event, and calculating the optimum amount of load to shed.
- Operate with much greater flexibility than fixed schemes, allowing different shedding responses for different types of events.
- Trigger based on a very broad variety of system conditions, including system events, frequency conditions, voltage conditions or a combination thereof.
- Act significantly faster than fixed schemes by calculating the available time for action and determining the appropriate operational trigger necessary to maintain system frequency within the bounds of the FOS. This may involve using high speed communication of a system event rather than sensing system frequency as the trigger for operation of the scheme (as in this case, the adaptive scheme does not wait for system frequency to drop before initiating load shedding).

[16] A similar mode of operation to the Tasmanian special protection scheme referenced on page 1 of the Consultation Paper

Q3b Is there a need for a framework to identify specific non-credible contingencies that AEMO should develop emergency frequency control schemes to address?

AEMO's view is that identification of specified non-credible or multiple contingencies, individually or by type, through a proposed '*protected events'* mechanism, will provide needed clarity as to how emergency frequency control schemes should be designed and operated. AEMO anticipates that the severity of the consequences of these events would be a key criterion for classification as 'protected'.

In addition to providing a clearer basis for management of extreme frequency conditions that may result from particular non-credible contingency events, the protected events framework provides a flexible mechanism for management of additional power system conditions that may emerge as the generation mix in the NEM continues to change, without the need for further changes to the NER.

Q3c Could this issue be addressed by AEMO reclassifying certain currently non-credible events as credible, under NER clause 4.2.3.A?

NER clause 4.2.3.A is not suitable for this purpose. The operative basis for reclassification as detailed in clause 4.2.3.A(b) is 'any *non-credible contingency* event which is more likely to occur because of the existence of *abnormal conditions*'.

Reductions in availability of online synchronous inertia in SA have given rise to the need to review existing mechanisms for management of extreme frequency events as it is unlikely that existing schemes can operate effectively under some power system conditions. It is expected that this trend of reducing synchronous inertia will continue and represents an enduring long-term structural change to the generation market, rather than an abnormal transient event with the potential to affect the power system. For this reason it is not easily administered under the provisions for abnormal conditions, which require the issue of market notices and other actions each time abnormal conditions occur or desist.

The current NER also do not allow reclassification where the likelihood of a particular non-credible contingency event has not increased, but the impact to the power system should it occur has. While clause 4.2.3.A has a limited role with respect to permanent alterations to power system characteristics, its current function in providing a mechanism to for temporary re-classification of a non-credible contingency events should be preserved.

2.4. Question 4- Governance arrangements

Q4a What roles should be played by different parties, including AEMO, NSPs, JSSCs, market participants and the Reliability Panel, in the framework for emergency frequency control?

Parties should have the following roles in implementation of emergency under-frequency management:

- AEMO to design OFGS and UFLS, in accordance with obligations to maintain power system security and the FOS, in order to operate as a last line of defence for NCCs/protected events (assumes provisions for participation and terms of operation of OFGS are included in the NER) based on advice from NSPs.

- NSPs should continue to observe obligations for load shedding provisions in connection agreements, perform design due diligence on schemes and promptly implement scheme design as agreed, including any necessary installation or upgrade of systems. NSPs should continue to observe obligations to ensure load shedding in accordance with clause S5.1.10 and development of emergency controls in accordance with clause S5.1.8 for non-credible contingency events/protected events.
- JSSCs should continue to provide advice on priority and sensitivity of loads in accordance with clause 4.3.2 (f) (although some changes to references to frequency in clause 4.3.2(j)(1) may be required. This clause provides that 'automatic *disconnection* of a *sensitive load* under clause 4.3.5(a) is not to occur until the occurrence of a specified *power system frequency* referred to in the *load shedding procedures*').
- Market customers (retailers) should continue to observe obligations under clauses 4.3.5 and S5.3.10 to provide load shedding. AEMO suggests that it may be necessary to revise clause 4.3.5(b), which reads 'within under-*frequency* bands from 49.0 Hz down to 47.0 Hz as nominated by *AEMO'*, to remove references to fixed frequency bands so that load may be shed more flexibly by adaptive schemes.
- The Reliability Panel would be well placed to administer a process for determining protected events and continue to advise on levels required to support load shedding under clause 4.3.5 (a) (see section 1.3).

Q4b What would an appropriate incentive regime for NSPs look like if they were tasked with additional roles in developing, monitoring and adapting emergency frequency control schemes?

- As independent system operator with responsibility for maintaining power system security, AEMO is best placed to undertake design and monitor the effectiveness of UFLS/OFGS schemes, because co-ordination across regions will be necessary. We expect this would include obligations to regularly review the operational efficacy of the schemes, which would likely involve consultation and participation from NSPs. As such, a scheme to incentivise NSPs in terms of development, monitoring and adaptation of schemes may not be necessary.
- Notwithstanding the above, NSPs should be required to maintain a watching brief on any changing characteristics of their network that have the potential to undermine efficacy of emergency frequency control schemes and promptly notify AEMO.
- AEMO encourages the AEMC to consider reasonable provisions for NSPs to recover costs associated with installation of additional communications and relay infrastructure as required for these schemes. These cost recovery provisions should incentivise the regular and timely review and revision of emergency frequency controls.
- AEMO encourages the AEMC to consider clarifying the obligations and rights of NSPs and other affected registered participants in clauses:
    - S5.1.10.1 in relation to 'multiple *contingency events'*; and

- S5.1.8 to '*consider non-credible contingency events*' in network planning.

2.5. Question 5- Costs to participants

Q5a What kind of costs are likely to be faced by participants if a new framework for emergency frequency control schemes is introduced?

AEMO anticipates that costs would be incurred in the following categories:

- AEMO and NSPs would expect to face design costs for development of an adaptive emergency frequency control scheme.
- NSPs would likely be subject to costs for new relay technology infrastructure costs for communications and IT equipment and ongoing costs for operation and maintenance of a scheme. A suitable cost recovery mechanism should be in place to allow NSPs to fund implementation, operation and maintenance of these schemes. This cost recovery mechanism should allow control schemes of this kind to be developed, implemented and modified in a timely manner, as required. In some respects, emergency frequency control schemes are a substitute for network investment, where the network infrastructure (or network support contract) would only be used in extreme conditions. The design of the scheme should take these costs into account.
- AEMO notes that it is likely that the same centralised supervisory control system used for an adaptive UFLS could be used to administer an OFGS scheme

2.6. Question 6- Managing over frequency events

Q5a What should a framework for managing extreme over frequency events look like?

Please refer to points on over frequency event management in section 1.2 of this submission, which provide a high level outline of a suitable framework structure.

AEMO notes that OFGS schemes are designed to address over-frequency conditions that otherwise have the potential to cause a cascading trip of generation and a subsequent under frequency event. If those schemes do not operate effectively, a black system condition may result. On that basis AEMO considers that compensation to generators for foregone revenues when the scheme operates is not justified, as generators would be disconnected in any case without operation of such schemes. The effect of functional OFGS schemes will be to increase generator access to the wholesale electricity market, by reducing the likelihood of prolonged and significant network outages.