Operational Application of Frequency Operating Standards

Discussion paper – July 2025

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PowerWater

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Definitions

TERM	DEFINITION
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AGC	Automatic Generator Control
C-FCAS	Contingency Frequency Control Ancillary Service as defined in the Secure System Guidelines
Credible Contingency	As defined within the Secure System Guidelines
DER	Distributed Energy Resources
ENTSOE	European Network of Transmission System Operators for Electricity
ESS	Essential System Services
Frequency Operating Standards	As defined within the Network Technical Code
Generator Performance Standards	As defined within the Network Technical Code
I-FCAS	Inertia Frequency Control Ancillary Service As defined within the Secure System Guidelines
NEM	National Electricity Market (Australian East Coast)
NERC	North American Electric Reliability Corporation
NTC	Network Technical Code
NTESMO	Collective acronym used interchangeably for the Power System Controller and Market Operator
OFGS	Over Frequency Generator Shedding
PFR	Primary Frequency Response
Regulated Power System	As defined within the System Control Technical Code. Refers to: • Darwin Katherine Power System • Tennant Creek Power System • Alice Springs Power System
R-FCAS	Regulating Frequency Control Ancillary Service as defined in the Secure System Guidelines
RoCoF	Rate of Change of Frequency
SCED	Security Constrained Economic Dispatch
SCTC	System Control Technical Code
SSG	Secure System Guidelines As defined within the System Control Technical Code
UFLS	Under Frequency Load Shedding
WEM	Wholesale Electricity Market (in Western Australia)

1 Introduction

The Northern Territory Electricity System and Market Operator (NTESMO) has undertaken a review of the operational application of the Frequency Operating Standards and the currently applied operational guidelines to modernise and adapt to the changing needs of the power system. The updated Secure System Guidelines specifies the expected frequency outcomes for the NT Regulated Power Systems.

Frequency Operating Standards in the System Control Technical Code (SCTC) and the Network Technical Code (NTC) specify the settings that provide limits within which for the power system should adhere to be securely operated. Settings can be upper or lower limit values or ranges, expressed in a variety of forms (e.g. minutes, Hz), which apply under different system and network conditions. Stable operation of the power system requires that frequency be maintained close to a nominal target of 50 Hz. Power system equipment, including generators, load and associated plant may disconnect from the power system if the system frequency becomes unstable and changes too quickly, or varies too far from 50 Hz. This can result in the disconnection of load and, in the worst cases, the collapse of all or part of the power system causing a system black and loss of supply to consumers.

Current Frequency Operating Standards are laid out in combination between the NTC, and the SCTC while the operational process is defined in the Secure System Guidelines. These were most recently reviewed in 2020 with the adoption of Generator Performance Standards being implemented. As a subset of wider market and industry reform, it has been identified that a review of the Frequency Operating Standards and their specific application is required to ensure appropriate standards inform reform and investment decisions. This discussion paper clarifies and proposes the application of existing Frequency Operating Standards.

The transformation and decarbonisation of the power system presents challenges and opportunities for the control of power system frequency. The reduction in synchronous thermal generation is expected to result in reduced levels of inertia that acts to resist changes in power system frequency and keep the grid stable. At the same time, new inverter-connected technologies, including renewable generation and battery energy storage systems have the capability to provide very fast active power response to changes in system frequency, if they are configured to do so. The revised operational application of the Frequency Operating Standards provides a basis for ongoing work to maintain system security and continue to integrate new technologies to build the power system of the future.

1.1 Core elements of the revised application of Frequency Operating Standards

The review of Frequency Operating Standards was undertaken with the view that the revised operational application should:

- be consistent with the adoption of a Security Constrained Economic Dispatch market model in accordance with the dispatch principles defined in the System Control Technical Code (clause 4.3) and a revised ESS framework.
- adopt a simplified and consistent approach to terminology and wording, where possible
- maintain consistency with current frequency settings, adapted to fit within the structure of the revised guidelines.
- be clear in how they must apply to the regulated power systems and any islanded systems.
- ensure definitions are technology-neutral, to the extent possible and
- support a robust and effective governance framework.

This discussion paper outlines the amendments to the application of Frequency Operating Standards, separated into sub-sections based on common themes. In reviewing the application, comparisons to the Western Australia's Wholesale Electricity Market (WEM)[1], the National Electricity Market (NEM)[2], United Kingdom, New Zealand, and Ireland Grid Codes[3] were made, along with consideration of the differences between the Regulated Systems of the NT and these other jurisdictions. This resulted in a decision to use consistent terms with the NEM, but with the continuation of existing settings, which in many cases are better suited to the needs of the NT.

The key elements of the revised guidelines, are:

- Introduction of system limits for rate of change of frequency following contingency events.
- Introduction of system limits for maximum contingency size.
- The introduction of a trial to removal the active correction of accumulated time error.
- General clarification of definitions and operating bands.

1.2 A Case for change

This review has consolidated and outlined changes required to be made to the Secure System Guidelines to ensure continued and future support to the secure and reliable operation of the power system. This work has been undertaken with regards to the context of market and industry reform currently being progressed within the Northern Territory Regulated Power Systems.

Deficiencies with the existing Frequency Operating Standards, technical codes, and current guidelines identified through this review were:

- References within current standards around key concepts were not adequately defined and supported.
- Ambiguous definitions and application of response, stabilisation, and recovery timeframes.

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[1] (Energy Transformation Taskforce, 2019)
[2] (AEMC Reliability Panel, 2023)
[3] (GHD Advisory, 2023); (ENTSOE, 2020)

- The absence of clear distinction regarding situations where Frequency Operating Standards do not apply in full.
- The non-alignment of the location of the frequency operation standards within the existing technical rules with regards to the primary roles and responsibilities associated with the standard, introducing challenges to the development of appropriate compliance and governance frameworks.

NTESMO has determined that the operational application of the Frequency Operating Standards will be defined to avoid ambiguity so it can direct the required outcomes in the ESS framework. Defining the application of the Frequency Operating Standards is a fundamental input in determining the type and quantity of ESS required, and therefore the cost of providing these services, which is ultimately borne by end users such as households and businesses. The increasing prevalence of distributed energy resources (DER), as well as changes in institutional arrangements are additional drivers for amendments to the guidelines outlined in this paper.

1.3 Consultation

The changes to the operational application of Frequency Operating Standards that are detailed in this paper will undergo a public industry consultation, with feedback being addressed as required after review.

2 New concepts

The Frequency Operating Standards generally define bands of frequency and time settings in relation to containment, stabilisation, and recovery of the system frequency. These bands are used to specify different stages of system recovery from a deviation in system frequency. Within the NEM, AEMO uses these parameters when determining ESS requirements. The narrower the band is, or the quicker the system frequency must return to a particular band, the greater the typical requirement for the ESS in that timeframe.

The NEM Frequency Operating Standards includes frequency and time settings for containment, stabilisation, and recovery of system frequency as explicit terms. While concepts of containment, stabilisation and recovery apply in the current WEM Frequency Operating Standards, they are not explicitly worded or defined. Defining these concepts will provide consistency of terminology, simplify the current Frequency Operating Standards, and allow them to be used in determining required ESS quantities.

In defining these concepts, there is no intention to modify existing frequency settings. The current settings will be adapted only to the extent necessary to enable their mapping across to the defined frequency-related terms.

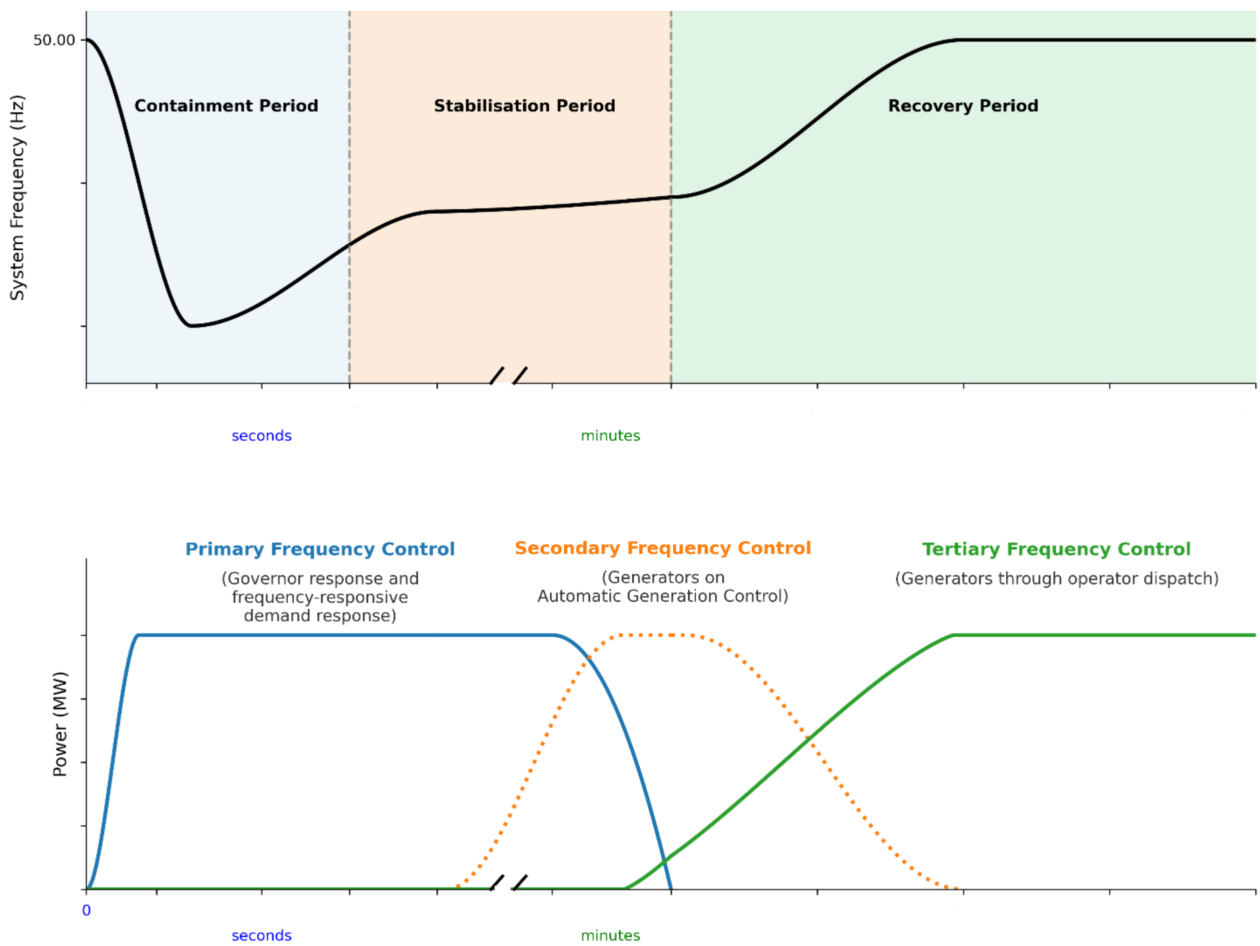
This review has concluded that:

- The NEM concepts of containment, stabilisation, and recovery will be utilised for the NT Regulated Power Systems. These concepts will be required to be defined in the future market rules as they are developed.
- The operational application of the frequency operating standard settings will be modified only to the extent necessary to align with newly adopted definitions and current operational requirements.

The following will become defined terms to be utilised in the NT Regulated Power Systems for use in the operational application of Frequency Operating Standards. They provide the allowable frequency ranges for various operating conditions and will be used to inform the requirements for future ESS procurement.

Each of the three defined times relate to a specific phase of the behaviour of frequency during an event and is tied to a distinct dominant type of frequency control. Operationally, the way in which the system transitions between Containment, Stabilisation, and Recovery will vary based on the specific circumstances of each power system disturbance. Figure 1 presents an illustration of the conceptual definition of the containment, stabilisation and recovery periods associated to contingency events. The illustration represents typical timeframes and actuals for each period is likely to differ dependent upon type of power system.

Figure 1 - Frequency and Operational Period Time domains - Conceptual illustration



- Containment
  - Containment is in general the time required for automatic actions taken by primary frequency control scheme's (e.g. Governor Droop and Inertia) to occur and to arrest and commence the initial recovery of frequency following a power system disturbance.
  - Containment will typically refer up to the initial 10 seconds of an event.
- Stabilisation

- Stabilisation is defined within the area of the Network Technical Code which specifies frequency and duration outside of normal frequency operating band under abnormal operating conditions. This generally refers to the time during an event where secondary frequency controllers (e.g. AGC) are the dominant driver of change; and the power system has entered a quasi-steady state where frequency has stabilised, but not necessarily returned to the normal operating band.
  - Typically, stabilisation will endure, based upon the configuration of the power system, for a period of up to 10 minutes.
  - The

- Recovery
  - Recovery is in general the time where tertiary frequency controls (e.g. Unit Commitment, Unit Dispatch) are the dominant driver of change. It is during this phase where frequency is expected to be fully recovered to normal, and the power system has transitioned back to normal operating conditions.
  - Typically, for a period from 10 minutes onwards and reflective of the time taken to commit additional generator capacity.

Each of the five defined frequency ranges relate to a specific method of control and behaviour of the power system. Operationally, the way in which the system transitions between range will vary based on the specific circumstances of each power system disturbance. Two of these ranges are specifically defined within the Frequency Operating Standards contained within the Network Technical Code[4], as noted.

- Primary Frequency Control Range
  - This represents the range of frequency operation typically maintained by general regulating control systems and is representative of the sensitivity of the primary frequency controllers.

- Normal Operating Frequency Band
  - This is a codified frequency band and represents the normal range of frequency operation. This is generally where the system will operate under normal conditions. No specific corrective actions are required to be taken when operating within this band.

- Normal Operating Frequency Excursion Range
  - Except as a result of a contingency event, this band allows infrequent/momentary excursions outside of the normal operating frequency band.
  - This range allows the flexibility in consideration by control room operators to make informed decisions as a result of operational circumstances that have a momentary deviance outside of the normal operating frequency band that are unrelated to contingency event.
  - Correction of frequency is expected to be primarily achieved by R-FCAS services.

- Credible Contingency Event Frequency Range
  - This represents the allowable frequency operating range for single credible contingency events. Generally, the power system should recover within this band without unduly impacting consumers.
  - It is fully expected that C-FCAS services are fully utilised within this range.

[4] (Power and Water Corporation, 2020)

- Abnormal Operating Frequency Band
  - This is the second codified frequency band and represents the minimum and maximum limits of operation generally expected within the power system. This represents the general limits of frequency operation under extreme non-credible contingency events.
  - It is fully expected that operations within this range have exhausted the availability of all associated R-FCAS, and C-FCAS services, and the operation of all relevant protection schemes (e.g. UFLS, OFGS) as invoked by the specific event.
  - Continuous operation within this band is undertaken as a reasonable endeavours approach.

Table 1 and Table 2 within Appendix A present the proposed application of Frequency Operating Standards in more detail. It is important to note that where “reasonable endeavours” has been identified that it remains within the intent of the Power System Controller to achieve the specified frequency band within the prescribed time to the extent possible without pursuing an inefficient or uneconomic approach. For example, the NTC prescribes a 10-minute maximum stabilisation time (aggregate stabilisation and recovery period) for regulated power systems to assume the normal operating frequency band; however, in the case of the DKPS, for certain power system operating conditions, this will require a substantial additional inefficient commitment of units to achieve the criterion presenting an economically unjustifiable outcome merely to meet a contingency stabilisation period. The Power System Controller is expediting actions to seek amendment of the provisions of the NTC in due course to enable a more realistic definition of the stabilisation time that aggregates the stabilisation and recovery periods.

These newly defined terms both make clear of the existing settings within the NT, as well as introduce new frequency ranges for use in future security assessments and planning. Having with these defined it will assist in the development of rules and related procedures.

3 ROCOF limit

The operational application of the Frequency Operating Standards includes new distinctions for the allowable RoCoF following credible and non-credible contingency events across the Northern Territory regulated power systems. These new requirements seek to define the system operating limits in the face of the expected reduction in inertia provided by synchronous generators as the generating fleet becomes increasingly dominated by inverter-based renewable generation. The revised application also includes separate RoCoF requirements for islanded systems and Tennant Creek. This is reflective of the different operational requirements for these regions.

These RoCoF limits are viewed as an initial step in terms of defining the operational boundary conditions and will inform future regulatory change as reform activities are progressed. Future revisions of the RoCoF limits will be informed by regulatory requirements on essential system services and information regarding withstand capability of the generation fleet as at the time of the reviews.

The revised limits of maximum allowable RoCoF have been informed by reviews undertaken in the NEM and WEM power systems. AEMC have made available publicly an international survey of RoCoF management that was completed by GHD. The approach taken within the NT context is consistent with the development within the NEM and WEM.

Power and Water has worked closely with Territory Generation over the years in understanding the technical capability of the existing fleet with regards to RoCoF withstand capability given the evidence observed within the Northern Territory Regulated Power Systems. This information has been used to assist in the development of the new applications.

The times noted below in the setting of the regional limits are taken as a moving average over the window noted.

A review of the regional applications of RoCoF will be triggered by substantive changes within the respective power system. This would be inclusive of the commissioning and/or decommissioning of assets that provide ESS or otherwise alter the operational dispatch of ESS.

Darwin-Katherine & Alice Springs

Credible Contingency Event:	+/- 1.35Hz/s over 250ms
Non-Credible Contingency Event:	+/- 4.00Hz/s over 250ms

Tennant Creek & Islanded Subsystems

Credible Contingency Event:	+/- 2.00Hz/s over 250ms (Reasonable Endeavours)
Non-Credible Contingency Event:	+/- 4.00Hz/s over 250ms (Reasonable Endeavours)

Table 1 and Table 2 within Appendix A detail the new Frequency Operating Standards including RoCoF.

4 Contingency event limit

The operational application of the Frequency Operating Standards includes a new guideline pertaining to the threshold for the maximum allowable contingency size within each regulated power system. The decision to enact an upper limit of contingency size is informed by jurisdictional comparisons to the NEM, WEM, and international power systems.

The limits proposed are based on current and likely future scenarios. This constraint applies to any part of the power system which is considered to be a single credible contingency, inclusive of generation, load, and network elements. A 60 MW maximum credible contingency limit has been proposed for application within the DKPS. The rationale for setting the limit at 60 MW is precipitated by a combination of the capacity of the largest loaded generating unit and the extent of likely loss of behind-the-meter inverter-based sources being curtailed due to exceeding pre-set voltage limits.

By placing a maximum contingency size limit within the operational application of the Frequency Operating Standards, a clear signal is sent to all system participants that the hosting capacity of the Northern Territory regulated power systems is constrained and bound by the low availability of adequate essential system services. By setting this as a clear parameter, transparent guidance is made available on the technical hosting capacity of the power systems. This will reduce the likelihood of unexpected outcomes during the connections process.

A more distinct outcome of the setting of a contingency size limit, is that when combined with the above declared RoCoF limits, system planning can be based on floor requirements for frequency-based ESS. Minimum requirements for both FCAS and Inertia can be well defined and sourced at a system level, permitting clear system planning guidance allowing for future investment to be planned and optimised. For example, by prescribing a maximum credible contingency limit of 60 MW for the DKPS, requires a minimum pre-contingent inertia of 1150 MWs to limit RoCoF to a practical limit of 1.35 Hz/s over 250 ms.

Practical operational application of a maximum contingency size will be dynamic in nature up to the determined maximum limits due to the changing drivers over the intervals in the dispatch horizon. At any instance in time, NTESMO will operate the system to be within the capacity and ESS capability of the power system.

Any future update or review of the maximum contingency size would be based on a combination of techno-economic and technical analysis into the feasibility of the proposed change precipitated by the evolution of the power system.

4.1 Application to NT regulated systems

Darwin- Katherine Power System

It has been determined that a contingency limit of 60 MW is suitable for the interconnected Darwin-Katherine Power System.

Alice Springs Power System

It has been determined that a contingency limit of 10 MW is suitable for the current Alice Springs Power System.

Tennant Creek Power System

Tennant Creek Power System is proposed to operate and be designed around a contingency limit of 2 MW for the purposes of future planning and investment.

5 Accumulated time error

Time error is a measure of the accumulated time the power system has spent above or below exactly 50 Hz. If the real power system frequency is persistently above or below 50 Hz, even by a small amount, then the actual flow of energy in the system may differ slightly from that assumed through the energy market. Over time such variations, left unchecked, can accumulate thereby shifting resulting in a misalignment between synchronous and real time.

This review has concluded the following, based on leveraging recent reviews within the WEM and NEM:

- Time error is a valuable metric in monitoring and reporting of wider frequency performance.
- Time error has an immaterial impact on electricity consumers.
- Time error has no security or reliability benefits to the power system.

As such, NTESMO will be seeking to undertake a trial in removing the requirement to actively correct time error, and the second requirement to maintain accumulated time error to within 15 seconds. Current reporting and monitoring of time error will continue to be obligated. This trial would be used to inform future code amendments to remove the specific obligations of time error correction.

Industry support and perspective is required to inform the future direction of the code amendments that would be required to formalise this stance upon the conclusion of the trial.

6 Future reviews

NTESMO will continue to monitor frequency performance and related developments. NTESMO will have a focus on the interactions between management of power system to within the new guidelines, and the transition to a new market framework around ESS.

Subsequent reviews of both the codified Frequency Operating Standards, and their operational application within respective guidelines should be informed by a consideration of a combination of techno-economic and technical analysis into the feasibility of the proposed change.

Significant reforms and changes to underlying dispatch arrangements of ESS would trigger a review of the applicability of the Frequency Operating Standards.

7 References

AEMC Reliability Panel. (2023, April 6). Appendix A - Frequency Operating Standard.

AEMC Reliability Panel. (2023, April 6). Information Sheet - Frequency Operating Standard Review.

AEMC Reliability Panel. (2023, April 6). Review of the Frequency Operating Standard.

AEMO. (2021, October 1). Guideline: Rate of Change of Frequency Sensitive Equipment.

Energy Transformation Taskforce. (2019, November). Revising Frequency Operating Standards in the SWIS.

ENTSOE. (2020, December 16). Inertia and Rate of Change of Frequency (RoCoF) - Version 17.

GE Energy Consulting. (2017, April 9). Advisory on Equipment Limits Associated with High RoCoF.

GHD Advisory. (2023, February 24). System Rate of Change of Frequency - GHD International Survey for AEMC.

North American Electric Reliability Corporation. (2023, September). Reliability Guideline - Primary Frequency Control.

Power and Water Corporation. (2020, March 30). Network Technical Code and Network Planning Criteria.

Power and Water Corporation. (2024, February 14). System Control Technical Code.

8 Appendix A – Operational Targets for Frequency

Table 1 – Operational Targets for Darwin-Katherine Interconnected and Alice Springs Power Systems

Frequency Band	Condition	Darwin Katherine Power System (Interconnected) Alice Springs Power System			
		Containment (Hz)	**Stabilisation (Hz)**	**Recovery (Hz)**	**ROCOF (Hz/s)**
Primary Frequency Control Band	Normal System Conditions, without credible contingency event	49.98 - 50.02	N/A	N/A	+/- 1.35 (Measured over 250ms)
Normal Operating Frequency Band		49.80 - 50.20 (99% of Time)	N/A	N/A	
Normal Operating Frequency Excursion Band	Operation not within Normal Operating Frequency Band	49.50 - 50.50	49.80 - 50.20 (Within 5 Minutes)	N/A	
Credible Contingency Event Frequency Band	With Occurence of Credible Contingency Event	48.60 - 51.00	49.50 - 50.50 (Within 2 Minutes) (Reasonable Endeavours)	49.80 - 50.20 (Within 10 Minutes) (Reasonable Endeavours)	
Abnormal Operating Frequency Band	Multiple Contingency Event	45.00 - 52.00 (Reasonable Endeavours)	Above 47.00 within 2 seconds Above 49.00 within 1 minute Below 51.50 within 1 minute Below 51.00 within 2 minutes 49.50 to 50.50 within 5 min (Reasonable Endeavours)	49.80 - 50.20 (Within 10 Minutes) (Reasonable Endeavours)	+/- 4.00 (Measured over 250ms) (Reasonable Endeavours)

Table 2 – Operational Targets for Darwin-Katherine Islands and Tennant Creek Power Systems

<table>
<tr><th rowspan="2">Frequency Band</th><th rowspan="2">Condition</th><th colspan="4">Darwin Katherine Power System (Islands)
Tennant Creek Power System</th></tr>
<tr><th>Containment (Hz)</th><th>Stabilisation (Hz)</th><th>Recovery (Hz)</th><th>ROCOF (Hz/s)</th></tr>
<tr><td>Primary Frequency Control Band</td><td rowspan="2">Normal System Conditions, without credible contingency event</td><td>49.95 - 50.05</td><td>N/A</td><td>N/A</td><td rowspan="4">+/- 2.00

(Measured over 250ms)
(Reasonable Endeavours)</td></tr>
<tr><td>Normal Operating Frequency Band</td><td>49.60 - 50.40
(99% of Time)</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Normal Operating Frequency Excursion Band</td><td>Operation not within Normal Operating Frequency Band</td><td>49.20 - 50.80</td><td>49.60 - 50.40
(Within 5 Minutes)</td><td>N/A</td></tr>
<tr><td>Credible Contingency Event Frequency Band</td><td>With Occurence of Credible Contingency Event</td><td>48.50 - 51.50
(Reasonable Endeavours)</td><td>49.20 - 50.80
(Within 2 Minutes)
(Reasonable Endeavours)</td><td rowspan="2">49.60 - 50.40
(Within 10 Minutes)
(Reasonable Endeavours)</td></tr>
<tr><td>Abnormal Operating Frequency Band</td><td>Multiple Contingency Event</td><td>45.00 - 52.00
(Reasonable Endeavours)</td><td>Above 47.00 within 2 seconds
Above 49.00 within 1 minute

Below 51.50 within 1 minute
Below 51.00 within 2 minutes

49.20 to 50.80 within 5 min
(Reasonable Endeavours)</td><td>+/- 4.00

(Measured over 250ms)
(Reasonable Endeavours)</td></tr>
</table>

9 Appendix B – Relevant code references

CODE REFERENCE	SHORT TITLE
NTC Clause 2.2	Power System Operating Frequency
NTC Clause 3.3.5.3	Generating Unit Response to Frequency Disturbance
NTC Clause 3.3.5.11	Frequency Control
NTC Clause 16.4	Frequency Stability Criteria
SCTC Clause 1.7.4	Obligations of the Power System Controller
SCTC Clause 2.2	Power System Security Responsibilities
SCTC Clause 3.2.6	Satisfactory Operating State
SCTC Clause 3.2.10	General Principles for Maintaining Power System Security
SCTC Clause 3.3.1	Responsibilities of the Power System Controller
SCTC Clause 3.3.2	The Power System Controller’s Role in Power System Security
SCTC Clause 3.5	Secure System Guidelines
SCTC Clause 4.3	Security Constrained Economic Dispatch
SCTC Clause 5.3	Frequency Control and Frequency Operating Standards

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