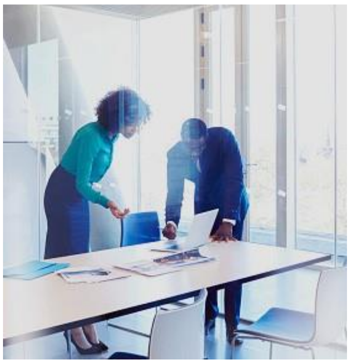
GHD Advisory



Review of GPS proposed by PWC and associated changes to NT technical regulations

Utilities Commission of the Northern Territory

Contents

1. Executive summary

GHD has completed a review for the Utilities Commission of the Northern Territory (the Commission) of the proposed changes to the Network Technical Code (NTC), the System Control Technical Code (SCTC) and the Secure System Guidelines (SSG) proposed by Power and Water Corporation (PWC). The focus of our review was the revisions to the NTC proposed by PWC to implement proposed generator performance standards (GPS) for the following Northern Territory (NT) power systems:

- Darwin Katherine Interconnected System (DKIS);
- Alice Springs power system, and
- Tennant Creek power system.

Our review considered whether the proposed GPS appropriately balances:

- the desire for system security;
- the costs imposed on generators needing to conform to the GPS; and
- the allocation of risk and cost among connecting generators, PWC and System Control.

This report presents the findings from our review which has specifically considered the following matters:

- alignment of the proposed GPS with the requirements in the National Electricity Rules (NER) and the National Electricity Rules as in force in the Northern Territory (NT NER). We have documented our review of each GPS clause identifying any variations between the GPS proposed by PWC and the access standards in the NER NT which reflect those in the National Electricity Market (NEM);
- whether differences between the GPS proposed by PWC and those applicable in the NEM are appropriate. This required consideration of the inherent difference between the characteristics of the interconnected east coast power systems that span the NEM and the power system in the Northern Territory operated by PWC (NT power systems). We found that for several clauses the GPS proposed by PWC differed from that in the NER NT, but those differences in most cases were justified by technical differences between the NT power systems and the power systems comprising the NEM;
- whether the technical characteristics of the NT power systems make it appropriate for PWC's proposed GPS to match those in the NER. While in many instances it was appropriate to match the NEM generator performance standards some departures were necessary to account for the technical differences between the NEM and the NT power systems;
- whether any inconsistencies between the technical requirements currently specified in the NTC, SCTC and SSG and the proposed GPS are appropriate;
- issues raised by stakeholders in submissions to PWC during its consultation on the proposed GPS; and
- whether the proposed GPS should be modified to better suit the technical characteristics of the Northern Territory power systems and the regulatory requirements in the Northern Territory.

Several stakeholders have raised concerns in their submissions to PWC that the introduction of the proposed GPS to NT power systems is not justified or that it is not necessary to make the proposed changes at this point in time. GHD has considered the case for introducing GPS and we believe that the introduction of an appropriate GPS framework is justified at this time.

The NT power systems like many across Australia and around the world are undergoing a period of significant change driven by the desire to reduce greenhouse gas emissions, while balancing affordability and reliability. In the NT significant growth in the amount of generation from solar power is expected in the near term. While the NTC currently includes generator technical requirements they are largely written for a power system with a generation fleet dominated by gas fired synchronous generators, those technical requirements need revision to remove technology bias and provide requirements that are applicable for future power systems incorporating a significant level of renewable generation such a large scale solar PV power stations.

Adopting a GPS framework in the NT power systems is consistent with reforms either recently completed or underway in other power systems across Australia. In September 2018 the Australian Energy Market Commission[1] completed a review of generator performance standards for the NEM. In Western Australia reforms are underway to replace the technical requirements for transmission connected generators participating in the Wholesale Electricity Market (WEM) with a GPS framework. The new GPS framework will be specified in the WEM Rules replacing the requirement currently specified in the Western Power Technical Rules. In 2018 Western Power and AEMO developed a generator performance guideline describing the proposed arrangements[2] which leverage the work undertaken by the AEMC.

By specifying appropriate performance requirements for all significant generators, a GPS framework provides greater certainty over the technical capability of the power system particularly as the generation mix evolves to include greater levels of solar generation. In the absence of a GPS framework uncertainty in generation performance leads to uncertainty in the system operator's assessment of system capability, which is likely to lead to either:

- Conservative operating limits leading to constraints on solar generation, or
- Unexpected insecure operation, risking customer load shedding.

While it is appropriate to introduce GPS we have recommended a number of revisions to the proposed GPS to clarify the performance requirement allowing generators to negotiate requirements that lead to efficient generation developments.

Section 3 of this report reviews each GPS clause proposed by PWC and presents the findings of our review including any recommended changes to the GPS.

Section 4 summarises our key findings addressing the following question raised by stakeholders:

- Is there a compelling need to introduce GPS across NT power systems at this time?
- Are the GPS proposed by PWC the appropriate set of standards for NT power systems?

[1] https://www.aemc.gov.au/rule-changes/generator-technical-performance-standards

[2] https://westernpower.com.au/media/3226/generator-performance-guideline.pdf

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2. Introduction

PWC has developed a proposed set of Generator Performance Standards (GPS) for generating systems connecting to the electricity networks they operate, specifically the:

- Darwin Katherine Interconnected System (DKIS);
- Alice Springs power system, and
- Tennant Creek power system.

The GPS will be given effect via amendments to the Network Technical Code (NTC), System Control Technical Code (SCTC); and Secure System Guidelines (SSG). The Commission is required to assess the proposed amendments to the NTC and the SCTC, having regard to the requirements of section 6(2) of the Utilities Commission Act 2000 (the Act).

In this context, the Commission has appointed GHD to assess the proposed GPS. The Commission has specifically requested advice in regard to the following matters:

- alignment of the proposed GPS with the requirements in the National Electricity Rules (NER) and the National Electricity Rules as in force in the Northern Territory (NT NER). The NER provisions are a reasonable benchmark, as the GPS framework has been operating in the National Electricity Market (NEM) for many years and was revised in 2018 following an extensive review undertaken by the Australian Energy Market Commission (AEMC). The GPS framework in the NER is encapsulated by the provisions in Clause 5.3.4A which describe the framework for negotiating GPS for new generators, Clause 5.3.9 which describes an equivalent process that applies when existing generators replace or upgrade elements of their plant and Schedule 5.2.5 which specifies the range within which each negotiated performance standard must lie. This schedule specifies minimum and automatic access standards for each aspect of technical performance encapsulated by the GPS;
- whether differences between the GPS proposed by PWC and those applicable in the NEM are appropriate. This requires consideration of the inherent difference between the characteristics of the interconnected east coast power systems that span the NEM and the power system in the Northern Territory operated by PWC (NT power systems);
- whether the technical characteristics of the NT power systems make it appropriate for PWC's proposed GPS to match those in the NER, particularly if these differ from technical requirements currently specified in the NTC, SCTC and SSG;
- whether any inconsistencies between the technical requirements currently specified in the NTC, SCTC and SSG and the proposed GPS are appropriate;
- issues raised by stakeholders in submissions to PWC during its consultation on the proposed GPS; and
- whether the proposed GPS should be modified to better suit the technical characteristics of the Northern Territory power systems and the regulatory requirements in the Northern Territory.

Understanding how generators will perform during normal operation, in response to contingency events, and the support that generators can provide to help regulate voltage and frequency and maintain a stable voltage and frequency is crucial in accurately determining system security limits. When a new generator is being proposed for connection it is important that there is clarity regarding the level of performance that the generator is required to deliver to ensure that its connection does not degrade the security of the power system below acceptable limits. While delivering a secure power system is the main objective of the GPS, consideration also needs to be given to the cost to conform to the GPS as well as the balance of risk and cost allocations across all connecting generators.

This report addresses these matters by examining the GPS proposed by the PWC, comparing the proposed GPS with the equivalent clauses in the NT NER and NER and where necessary recommending changes to the proposed GPS so that a secure network can be maintained with an appropriate allocation of costs and risks.

2.1 Structure of the report

The following sections of the report examine in turn each of the key changes proposed by PWC to implement the GPS. We first consider the changes proposed to the NTC to implement the GPS framework and each of the technical requirements that comprise the GPS. The final sections consider the proposed transitional arrangements and alignment between the NTC and the SCTC.

Each section is organised as necessary to present the following information:

- **Wording proposed by PWC** - presents revisions to the NTC proposed by PWC to present the relevant aspect of the GPS framework
- **Observations and Issues Identified –** presents GHD's assessment of the revisions to the NTC proposed by PWC against the criteria described in section 2 and recommends any changes to the wording of the GPS provisions.
- **Recommended Wording** – presents the recommended drafting for the relevant portion of the NTC incorporating suggested revisions to implement the recommended revisions. Highlighting has been used to identify the nature of the proposed change:
    - yellow highlight – indicates recommended formatting to identify defined terms which should be included in the glossary of terms - Attachment 1 of the NTC
    - green highlight – indicates changes to the proposed wording.

Where our review has not identified any need to alter the wording proposed by PWC this is noted in the main section and no subsections are included.

3. Review of Proposed GPS

3.1 NTC Clause 3.3 preamble and Clause 3.3.1 – Outline of Requirements

The preamble included at the beginning of clause 3.3 is appropriate and explains the derivation of the GPS requirements from the relevant sections of the NER. This inclusion provides a link to the NER requirements which may assist connection applicants and PWC when negotiating any performance standard as in some instances the NER provides additional material on the basis for negotiation that has not been included in the NTC.

As the NTC implementation of generator performance standards does not provide for explicit minimum and automatic standards for each technical requirement, it is difficult to include the basis for negotiation provisions from the NER into the NTC.

Clause 3.3.1 provides an outline of the requirements for generators negotiating their GPS. The proposed wording is appropriate as it includes provisions based on NER S5.2.1 modified as necessary to reflect the differences between the NT power systems and electricity markets and the NEM. GHD does not recommend any change to these clauses. The close alignment of the proposed drafting to the relevant schedule in the NER will help reduce the implementation costs as many generation developers will be able to leverage NEM experience.

3.2 NTC Clause 3.3.2 – Application of Settings

Clause 3.3.2 provides an outline of the requirements for generators negotiating their GPS. The proposed wording is appropriate as it includes provisions based on NER S5.2.2 modified as necessary to reflect the differences between the NT power systems and electricity markets and the NEM. GHD does not recommend any change to these clauses. The close alignment of the proposed drafting to the relevant schedule in the NER will help reduce the implementation costs as many generation developers will be able to leverage NEM experience.

3.3 NTC Clause 3.3.3 – Technical Matters to be Co-ordinated

Clause 3.3.3 provides an outline of the requirements for generators negotiating their GPS. The proposed wording is appropriate as it includes provisions based on NER S5.2.3 modified as necessary to reflect the differences between the NT power systems and electricity markets and the NEM. GHD does not recommend any change to these clauses. The close alignment of the proposed drafting to the relevant schedule in the NER will help reduce the implementation costs as many generation developers will be able to leverage NEM experience.

Sub-clause (d) in the NTC does differ from the requirements in the NER, by requiring generators produce a signed statement to certify that the equipment to be connected has been designed and installed in accordance with the NTC, all relevant standards, all statutory requirements and good electricity industry practice. GHD is satisfied that this clause should be retained as it reflects requirements that have historically been included in the NTC (clause 3.1.1.11(b) in the current version of the NTC), and therefore should not impose any significant additional cost on generators seeking to negotiate a GPS.

3.4 NTC Clause 3.3.4 – Provision of Information

3.4.1 Wording proposed by PWC

(a) A *Generator* shall provide the data specified in clause 11.2.

(b) The *Generator* shall provide all other data reasonably required by the *Network Operator*. This data shall include, without limitation, full models (and all model parameters) of:

(1) the *generating units*;

(2) the excitation control systems;

(3) turbine / engine governor systems; and

(4) power system stabilisers;

(5) to enable the *Network Operator* to conduct dynamic simulations.

(c) These models shall be in a form which is compatible with the power system analysis software used by the *Network Operator* (currently PSS/E from Siemens PTI and PowerFactory) and shall be inherently stable.

(d) Details of the kinds of data that may be required are included in Attachment 3 of this Code, specifically:

(1) Schedule S3.1 - Generating unit design data;

(2) Schedule S3.2 - Generating unit setting data;

(3) Schedule S3.5 - Network and plant technical data; and

(4) Schedule S3.6 - Network plant and apparatus setting data.

3.4.2 Observations and Issues Identified

Clause 3.3.4 specifies the information generators are required to provide. This clause reflects the requirements previously specified in Clause 11 of the NTC and is similar in many respects to the requirements specified in NER NT S5.2.4. The key areas of difference are:

- the NER NT specifies additional details regarding when generator modelling information is to be provided and updated following plant commissioning tests.
- the NER NT provides more detail regarding the modelling requirements. It specifies that generators must satisfy the modelling requirements in the Power System Model Guidelines that AEMO is required to develop via NER clause S5.5.7.
- the NER NT clarifies that both electromagnetic transient (EMT) and Root Mean Square (RMS) models are required to be provided. In contrast the NTC provisions only explicitly mention the provision of a PSS/E model which is an RMS model.

GHD does not recommend implementing changes to address the first two points as the NTC process generally lacks the timing details for the connection process included in the NER NT, and there are no power system model guidelines published for the NT power systems.

It is becoming increasingly important to have access to EMT models to be able to study the interactions of grid scale inverter connected renewable generating systems. EMT models are required to apply the detailed system strength assessment defined in the AEMO guidelines that are required to be applied under the system strength requirements of the GPS as proposed by PWC. GHD therefore recommends revising sub-paragraph (b) to clarify that both RMS and EMT models are to be provided if requested by PWC.

PWC have confirmed that they routinely ask connection applicants to provide both RMS and EMT models, as such the recommended refinement should not add significant incremental cost to generation applicants.

3.4.3 Recommended Wording

Clause 3.3.4

(a) A Generator shall provide the data specified in clause 11.2.

(b) The *Generator* shall provide all other data reasonably required by the *Network Operator*. This data shall include, without limitation, full Electromagnetic Transient (EMT) and Root Mean Square (RMS) models (and all model parameters) of:

(1) the *generating units*;

(2) the excitation control systems;

(3) turbine / engine governor systems; and

(4) power system stabilisers;

(5) to enable the *Network Operator* to conduct dynamic simulations.

(c) These models shall be in a form which is compatible with the power system analysis software used by the *Network Operator* (currently PSS/E from Siemens PTI and PowerFactory) and shall be inherently stable.

(d) Details of the kinds of data that may be required are included in Attachment 3 of this Code, specifically:

(1) Schedule S3.1 - Generating unit design data;

(2) Schedule S3.2 - Generating unit setting data;

(3) Schedule S3.5 - Network and plant technical data; and

(4) Schedule S3.6 - Network plant and apparatus setting data.

3.5 NTC Clause 3.3.5 – Technical Requirements

3.5.1 Wording proposed by PWC

The following technical requirements describe the *automatic access standards* for new or modification of existing, *generating units* or *generating systems* seeking connection to the network. A connection applicant may propose an alternative *negotiated access standard* by applying the following:

(a) A *negotiated access standard* must:

(1) be set at a level that will not adversely affect power system security;

(2) be set at a level that will not adversely affect the quality of supply for other *Network Users*.

(b) When submitting a proposal for a *negotiated access standard*, a connection applicant must propose a standard that is as close as practicable to the corresponding automatic access standard, having regard to:

(1) the need to protect the plant from damage;

(2) power system conditions at the location of the proposed connection;

and

(3) the commercial and technical feasibility of complying with the automatic access standard with respect to the relevant technical requirement.

(c) When proposing a *negotiated access standard* under paragraph (b), the connection applicant must provide reasons and evidence to the *Network Operator* and *Power System Controller* as to why, in the reasonable opinion of the connection applicant, the proposed *negotiated access standard* is appropriate, including:

(1) how the connection applicant has taken into account the matters outlined in subparagraphs (b)(1) to (3); and

(2) how the proposed *negotiated access standard* meets the requirements of paragraph (a).

3.5.2 Observations and Issues Identified

NTC clause 3.3.5 allows for a negotiated performance standard to be proposed by a connection applicant but places no obligation on PWC with respect to how it responds to the proposed standard. In contrast the NER process requires the NSP to consider various matters in developing its response and to respond providing specific information and meeting a specified timeframe. The NER process helps to progress to a negotiated outcome. The absence of such provisions is a deficiency likely to add cost to generation developers. It is reasonable to include in the NTC details regarding the information PWC should provide in response to a submitted GPS. GHD recommends that the NTC be amended to include a provision requiring PWC to provide adequate feedback in response to any submitted GPS.

This clause assumes the generator is able to provide evidence to support a proposed negotiated standard. A similar process exists in the NEM and is facilitated by intending participants can access modelling data via various rule provisions. Those NER provisions in Clause 3.13.3 k (2) are missing in the NER NT. The lack of any such provision in the NTC may impede generators for accessing the information required to efficiently negotiate a generator performance standard.

GHD recommends that the NTC be amended to include provisions providing adequate access to power system modelling information to generation proponents, with appropriate confidentiality arrangements surrounding such information. PWC have confirmed that this approach is necessary as without the explicit inclusion in the NTC confidentiality provisions in the NER NT may impede information disclosure.

Revisions to the NTC proposed by GHD are included in section 3.5.3. Adopting these revisions are likely to deliver a more efficient connection process and are therefore recommended. The proposed revisions also require the addition of a definition for confidential information into the NTC glossary.

3.5.3 Recommended Wording

Clause 3.3.5

The following technical requirements describe the *automatic access standards* for new or modification of existing, *generating units* or *generating systems* seeking connection to the network. A connection applicant may propose an alternative *negotiated access standard* by applying the following:

(a) A *negotiated access standard* must:

(1) be set at a level that will not adversely affect power system security;

(2) be set at a level that will not adversely affect the quality of supply for other *Network Users*.

(b) When submitting a proposal for a *negotiated access standard*, a connection applicant must propose a standard that is as close as practicable to the corresponding automatic access standard, having regard to:

(1) the need to protect the plant from damage;

(2) power system conditions at the location of the proposed connection;

and

(3) the commercial and technical feasibility of complying with the automatic access standard with respect to the relevant technical requirement.

(c) When proposing a *negotiated access standard* under paragraph (b), the connection applicant must provide reasons and evidence to the *Network Operator* and *Power System Controller* as to why, in the reasonable opinion of the connection applicant, the proposed *negotiated access standard* is appropriate, including:

(1) how the connection applicant has taken into account the matters outlined in subparagraphs (b)(1), (b)(2) and (b)(3); and

(2) how the proposed *negotiated access standard* meets the requirements of paragraph (a).

(d) Within 30 business days following the later of:

(1) receipt of a proposed *negotiated access standard*; and

(2) receipt of all information required to be provided by the connection applicant,

the *Network Operator* must accept or reject a proposed *negotiated access standard*.

(e) The *Network Operator* must reject the proposed *negotiated access standard* where in the *Network Operator's* reasonable opinion, one or more of the requirements at subparagraphs (a)(1) and (a)(2) are not met.

(f) If the *Network Operator* rejects a proposed *negotiated access standard*, the *Network Operator* must, at the same time:

(1) subject to obligations in respect of *confidential information*, provide to the connection applicant:

(i) where the basis for the *Network Operator's* rejection is lack of evidence from the connection applicant, details of the additional evidence of the type referred to in paragraph (c) the *Network Operator* requires to continue assessing the proposed *negotiated access standard*;

(ii) detailed reasons in writing for the rejection, including the extent to which each of the matters identified at subparagraphs (a)(1) and (a)(2) contributed to the *Network Operator's* decision to reject the proposed *negotiated access standard*; and

(2) advise the connection applicant of a *negotiated access standard* that the *Network Operator* considers meets the requirements of subparagraphs (a)(1), and (a)(2).

(g) The connection applicant may in relation to a proposed *negotiated access standard* advised by the *Network Operator* in accordance with subparagraph (f)(2):

(1) accept the proposed *negotiated access standard*;

(2) reject the proposed *negotiated access standard*;

(3) propose an alternative *negotiated access standard* to be further evaluated in accordance with the criteria in paragraph (b); or

(3) elect to adopt the relevant *automatic access standard* or a corresponding plant standard.

(h) An *automatic access standard* or if the procedures in this clause 3.3.5 have been followed a *negotiated access standard*, that forms part of the terms and conditions of a *connection agreement*, is taken to be the performance standard applicable to the connected plant for the relevant technical requirement

Network Modelling Information

(i) A connection applicant may request from the *Network Operator*:

(1) information that is reasonably required by the connection applicant to carry out power system simulation studies (including load flow and dynamic simulations) for planning and operational purposes; and

(2) operation and maintenance procedures and practices for network operation, sufficient to enable the connection applicant to carry out power system modelling under normal, outage and emergency conditions.

(j) If the *Network Operator* holds information requested under paragraph (i), the *Network Operator* must provide the requested information to the connection applicant as soon as practicable, subject to the following requirements:

(1) If the *Network Operator* holds and is required under this paragraph (j) to provide a releasable user guide that the *Network Operator* received from a *Generator*, the *Network Operator* must provide the releasable user guide to the connection applicant in an unaltered form.

(2) If the *Network Operator* holds and is required under this paragraph (j) to provide a form of the model source code that the *Network Operator* received from a *Generator* or from any other source, the *Network Operator* must provide that information:

(i) only in the form of, at the *Network Operator's* discretion:

(A) compiled information (such as, for example, compiled Fortran code in object code or dynamic link library (DLL) form);

(B) encrypted information; or

(C) a secured format agreed by the provider of the model source code,

unless the *Network Operator* has the written consent of the person who provided the information to the *Network Operator* to provide it in another form; and

(ii) in a form that can be interpreted by a software simulation product nominated by the *Network Operator*.

(3) Any information provided by the *Network Operator* under paragraph (j) to a connection applicant must be treated as *confidential information*.

The following definition needs to be added to the glossary of terms in Attachment 1 of the NTC:

confidential information

In relation to a *Generator* or *Network Operator*, information which is or has been provided to that *Generator* or *Network Operator* under or in connection with the *Code* and which is stated under the *Code* or by the *Network Operator* or by the *Utilities Commission* to be *confidential information* or is otherwise confidential or commercially sensitive. It also includes any information which is derived from such information.

3.6 NTC Clause 3.3.5.1 – Reactive Power Capability

3.6.1 Wording proposed by PWC

(a) The automatic access standard is a *generating system* operating at:

(1) any level of active power output; and

(2) any voltage at the connection point within the limits established under clause 15.2 (a) without a contingency event,

must be capable of supplying and absorbing continuously at its *connection point* an amount of reactive power of at least the amount equal to the product of the rated active power of the *generating system* and 0.395.

(b) A performance standard must record the agreed value for rated active power and where relevant the method of determining the value.

(c) A performance standard for consumption of energy by a *generating system* when not supplying or absorbing reactive power under an ancillary services agreement is to be established under clause 3.6 as if the *Generator* were a load.

3.6.2 Observations and Issues Identified

This clause differs from NER NT by the absence of guidance regarding the basis for negotiation or ability for connecting party to meet requirements by funding network investments. Revising the NTC to address these issues provides greater flexibility for generators when deciding on how best to achieve compliance with reactive power requirements. Greater flexibility has to potential to lead to more efficient connection options.

GHD recommends that wording be added that provides guidance for the negotiation of access standards and that a connecting party has the ability to meet the performance standard by funding network investments to achieve the required outcome.

The wording proposed by PWC reflects the automatic access standard specified in the NER NT. This level of reactive power capability is generally able to be delivered by generating systems, but will often involve additional capital expenditure. Should those costs threaten the commercial feasibility of the project, the generator may seek to negotiate a lower level of performance via the process described in clause 3.3.5 of the NTC. The additional revisions proposed by GHD provide further opportunities to optimise the investment necessary to provide reactive power capability. GHD therefore considers that the proposed standard is appropriate as it balances the costs imposed on generators and the system security benefits achieved by having generators provide adequate reactive power capability to control voltage.

It is recommended that the wording shown in section 3.6.3 is adopted.

3.6.3 Recommended Wording

Clause 3.3.5.1

(a) The *automatic access standard* is a *generating system* operating at:

(1) any level of *active power* output; and

(2) any *voltage* at the *connection point* within the limits established under clause 15.2 (a) without a *contingency event*,

must be capable of supplying and absorbing continuously at its *connection point* an amount of *reactive power* of at least the amount equal to the product of the *rated active power* of the *generating system* and 0.395.

(b) A performance standard must record the agreed value for *rated active power* and where relevant the method of determining the value.

(c) A performance standard for consumption of energy by a *generating system* when not supplying or absorbing *reactive power* under an ancillary services agreement is to be established under clause 3.6 as if the *Generator* were a load.

(d) If the *generating system* is not capable of the level of performance established under paragraph (a) the *Generator*, depending on what is reasonable in the circumstances, must:

(1) pay compensation to the *Network Operator* for the provision of the deficit of *reactive power* (supply and absorption) from within the *network*;

(2) install additional equipment *connecting* at the *generating system's connection point* or another location, to provide the deficit of *reactive power* (supply and absorption), and such equipment is deemed to be part of the *generating system*;

(3) reach a commercial arrangement with a *User* to provide the deficit of *reactive power* (supply and absorption); or

(4) if the inability to meet the performance level only occurs for particular operating conditions, agree to and document as part of the proposed *negotiated access standard*, operational arrangements by which the *plant* can achieve an agreed level of performance for those operating conditions.

(e) The *Generator* may select one or more options referred to in paragraph (d).

3.7 NTC Clause 3.3.5.2 – Quality of Electricity Generated

3.7.1 Wording proposed by PWC

(a) For the purpose of this clause 3.3.5.2 in respect of a synchronous generating unit, AS 1359.101 and IEC 60034-1 are plant standards for harmonic voltage distortion.

(b) The automatic access standard is a *generating system* when generating and when not generating must not produce at any of its connection points for generation:

(1) voltage fluctuation greater than the limits allocated by the *Network Operator* under clause 2.4.1;

(2) harmonic voltage distortion greater than the emission limits specified by a plant standard under paragraph (a) or allocated by the *Network Operator* under clause 2.4.2; and

(3) voltage unbalance greater than the limits allocated by the *Network Operator* in accordance with clause 2.4.3.

3.7.2 Observations and Issues Identified

This clause differs from NER NT as the automatic access level does not define the process used to allocate the harmonic emission limits, or voltage unbalance limits for connecting generators. NTC clause 2.4.1 and

2.4.2 lack the specific details included in the corresponding sections of S5.1.5 of the NER NT. The presently proposed drafting risks creating ambiguity and confusion regarding the applicable performance requirement.

There is a need for PWC to allocate specific limits to individual generators. Consequently it is recommended that Clauses 2.4.1 and 2.4.2 be revised to provide additional clarity.

The recommended revisions will provide a more efficient connection process by providing generators with greater clarity regarding the performance standards they need to meet. With the recommended changes implemented the performance standards will reflect the automatic access standard specified in the NER NT. That standard may require a solar farm to install harmonic filters to meet the automatic access standard, however that cost is justified if it is required to ensure the system standards are met thereby avoiding exposing other connected parties to quality of supply issues. GHD recommends adopting the wording proposed in section 3.7.3 as they provide an appropriate balance between the costs imposed on generators in meeting the standard and the quality of supply benefits delivered.

3.7.3 Recommended Wording

Clause 3.3.5.2

(a) For the purpose of this clause 3.3.5.2 in respect of a *synchronous generating unit*, AS 1359.101 and IEC 60034-1 are *plant standards* for harmonic *voltage* distortion.

(b) The *automatic access standard* is a *generating system* when generating and when not generating must not produce at any of its *connection points* for *generation*:

(1) *voltage* fluctuation greater than the limits allocated by the *Network Operator* under clause 2.4.1;

(2) harmonic *voltage* distortion greater than the emission limits specified by a *plant standard* under paragraph (a) or allocated by the *Network Operator* under clause 2.4.2; and

(3) *voltage* unbalance greater than the limits allocated by the *Network Operator* in accordance with clause 2.4.3.

Clause 2.4.1

2.4.1 Voltage fluctuations

A voltage disturbance is where the voltage shape is maintained but the voltage magnitude varies and may fall outside the steady state supply voltage range set out in clause 15.2 of the Network Planning Criteria. Short duration voltage disturbances of durations of up to one minute are termed voltage sags and swells. The ENA publication Customer Guide to Electricity Supply contains information on the typical voltage sags experienced on Australian electricity networks and how customers can mitigate the risks of equipment maloperation because of sags. Rapid voltage fluctuations cause changes to the luminance of lamps, which can create the visual phenomenon termed flicker.

(a) Under normal operating conditions, fluctuations in voltage on the network should be less than the “compatibility levels” defined in Table 1 of Australian Standard AS/NZS 61000.3.7 (2001).

(b) To facilitate the application of this standard Power and Water shall establish “planning levels” for its networks, as provided for in the Australian Standard.

(c) The *Network Operator* must allocate emission limits to a *connection applicant* that are no more onerous than the lesser of the acceptance levels determined in accordance with either of the stage 1 or the stage 2 evaluation procedures defined in AS/NZS 61000.3.7:2001.

Clause 2.4.2

2.4.2 Harmonic distortion

2.4.2.1 Harmonic voltage distortion

(a) Under normal operating conditions, the harmonic voltage in the network shall be less than the “compatibility levels” defined in Table 1 of Australian Standard AS/NZS 61000.3.6 (2001).

(b) To facilitate the application of this standard Power and Water shall establish “planning levels” of harmonic distortion for its networks as provided for in the Australian Standard.

(c) Planning levels for harmonic voltage distortion are specified in clause 17 of the Network Planning Criteria.

(d) The *Network Operator* must allocate emission limits to a *connection applicant* that are no more onerous than the lesser of the acceptance levels determined in accordance with either of the stage 1 or the stage 2 evaluation procedures defined in AS/NZS 61000.3.6:2001.

2.4.2.2 Non-integer harmonic distortion

Inter-harmonic or non-integer harmonic distortion may arise from large converters or power electronics equipment with Pulse Width Modulation (PWM) converters interfacing with the power system.

(a) Under normal operating conditions, the emission levels for inter-harmonic voltage in the network shall be less than the levels defined in section 9 of Australian Standard AS/NZS 61000.3.6 (2001).

(b) To facilitate the application of this standard Power and Water shall establish “planning levels” of inter-harmonic distortion for its networks as provided for in the Australian Standard AS/NZS 61000.3.6 (2001).

(c) Planning levels for inter-harmonic voltage distortion are specified in clause 17 of the Network Planning Criteria.

(d) The *Network Operator* must allocate emission limits to a *connection applicant* that are no more onerous than the lesser of the acceptance levels determined in accordance with either of the stage 1 or the stage 2 evaluation procedures defined in AS/NZS 61000.3.6:2001.

2.4.2.3 Voltage notching

Voltage notching may also arise from large convertors or power electronics equipment with Pulse Width Modulation (PWM) converters interfacing with the power system.

Voltage notching caused by a User's facilities is acceptable provided that:

(a) the limiting values of harmonic voltage distortion as described in clause 2.4.2.1 are not exceeded;

(b) the average of start notch depth and end notch depth shall not exceed 20% of the nominal fundamental peak voltage; and

(c) the peak amplitude of oscillations due to commutation at the start and end of the voltage notch shall not exceed 20% of the nominal fundamental peak voltage.

2.4.2.4 Harmonic current distortion

(a) The harmonic voltage distortion limits of clause 2.4.2 apply to each phase and are not to be exceeded by a User injecting harmonic currents at any of its connection points.

(b) Any induced noise interference to telecommunications lines by a User's load due to harmonic currents is not acceptable and the User is required to reduce the level of harmonic currents so as to contain such interference to limits considered acceptable by the telecommunication Network Operator.

(c) The User's load shall not cause any harmonic resonance in other Users' systems or the Network Operator's network.

2.4.2.5 Direct current

(a) Users' plant and equipment shall comply with the requirements on direct current components as stipulated in clause 3.12 of Australian Standard AS/NZS 3100:2009. In particular, the direct current in the neutral caused by the Users' plant and equipment shall not exceed 120mA.h per day.

(b) Users shall ensure that all their plant and equipment is designed to withstand without damage or reduction in life expectancy the limits as specified in this clause 2.4.2.5.

(c) Responsibility of the Network Operator for direct current in the neutral outside the limits specified in this clause 2.4.2.5 shall be limited to direct current in the neutral caused by network assets.

(d) A User whose plant is identified by the Network Operator as not performing to the standards specified in this clause 2.4.2.5 shall take such measures as may be necessary to meet Australian Standard AS/NZS 3100:2009.

3.8 NTC Clause 3.3.5.3 – Generating Unit Response to Frequency Disturbance

3.8.1 Wording proposed by PWC

(a) For the purposes of this clause 3.3.5.3:

normal operating frequency band and abnormal frequency band are references to the widest range specified for those terms for any condition (including an “island” condition) in the *frequency operating standards* that apply to the *region* in which the *generating unit* is located.

stabilisation time means the longest times allowable for the *frequency* of the *power system* to remain outside the normal operating frequency band, for any condition (including an “island” condition) in the *frequency operating standards* that apply to the *region* in which the *generating unit* is located.

transient frequency limit and transient frequency time mean the values of 45 Hz and 2 seconds respectively, or such other values determined by the *Power System Controller*.

(b) The automatic access standard is a generating system and each of its generating units must be capable of continuous uninterrupted operation for frequencies in the following ranges:

(1) the lower bound of the transient frequency limit for at least 2 seconds;

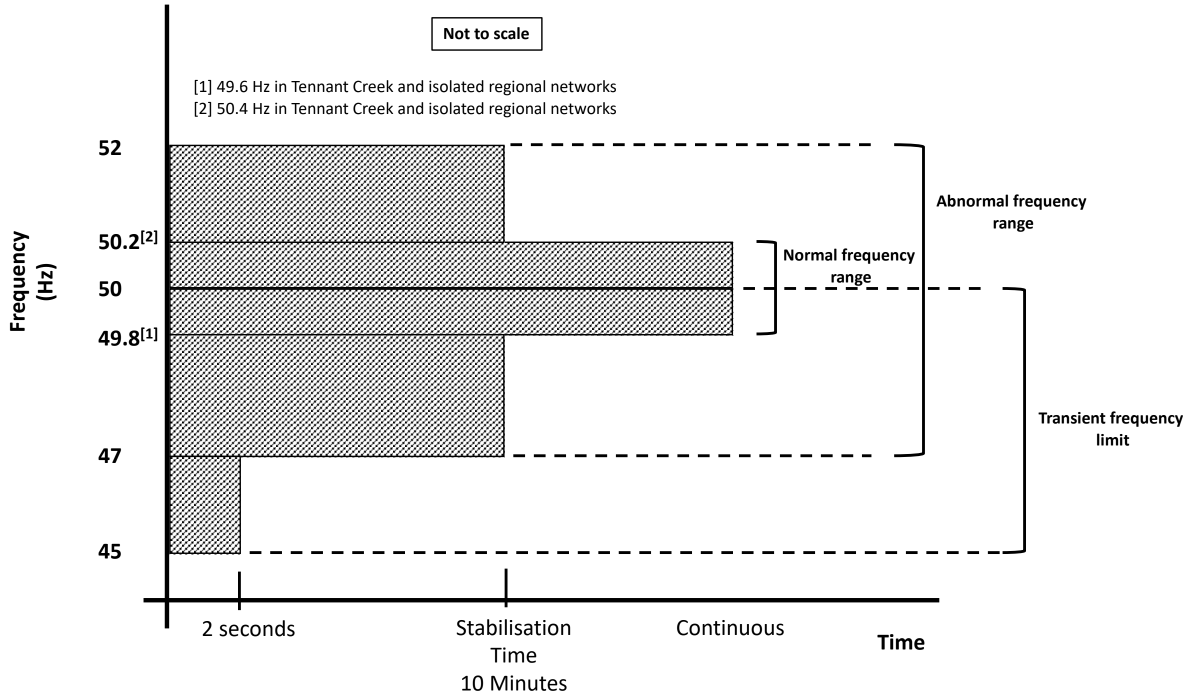
(2) the lower bound of the abnormal frequency excursion tolerance limits to the lower bound of the operational frequency tolerance band for at least the stabilisation time;

(3) the normal operating frequency band for an indefinite period;

(4) the upper bound of the operational frequency tolerance band to the upper bound of the abnormal frequency excursion tolerance limits for at least the stabilisation time,

unless the *rate of change of frequency* is outside the range of –4 Hz to 4 Hz per second.

The automatic access standard is illustrated in the following diagram reflecting the frequency standards outlined in clauses 2.2.1 and 2.2.2.



3.8.2 Observations and Issues Identified

In this clause the performance requirement is not adequately defined as terms that are referenced are not defined:

- abnormal frequency excursion tolerance limits;
- operational frequency tolerance band.

It is recommended the following defined terms be used instead:

- “operational frequency tolerance band” replaced by “normal operating frequency band”;
- “abnormal frequency excursion tolerance limits” replaced by “the limits of the abnormal operating frequency excursion band specified in 2.2.2(b)”.

Other issues:

- stabilisation time is not defined in the frequency operating standard which according to the glossary is defined in clauses 2.2 and 2.4 on the NTC. The definition of stabilisation time should be amended to clarify that it is 10 minutes.
- RoCoF is not specified with any time dimension making the requirement more onerous than the automatic access standard specified in the NER NT. The NER NT automatic requirement specifies generators ride though RoCoF of +/- 4Hz/s for 0.25s and +/- 3Hz/s for 1s. The Western Australia South West Interconnected System (SWIS) GPS reforms are seeking to establish similar RoCoF requirements to NER NT. The AEMC review identified some thermal generators may not be able to meet these requirements and the minimum limits in the NER NT and proposed SWIS GPS recognize that by setting less onerous limits of +/- 2Hz/s for 250 ms and +/- 1Hz/s for 1s.

RoCoF issues primarily affect synchronous generators, they are not a significant issue for solar PV inverter based generators due to their ability to respond rapidly to changes of frequency. PWC has advised that the isolated nature of the NT power systems means that following contingencies the frequency changes more rapidly than in larger interconnected systems such as the NEM. PWC have advised that the synchronous generators connected to NT power systems have demonstrated an ability to ride through relatively high RoCoF events and furthermore at a RoCoF of 4Hz/s the limits of the frequency ride-through bands specified in NTC clause 3.3.5.3 are reached quickly. PWC have therefore suggested that specifying a time dimension for RoCoF performance is not necessary. GHD believes that there is merit in this argument and does not recommend any change to the RoCoF provisions proposed by PWC.

The access standard proposed by PWC is consistent with the automatic access standard specified in the NER NT allowing for changes to the frequency settings to reflect the frequency operating standards applicable in NT power systems. The proposed access standards should not impose any significant cost on new generators particularly inverter connected solar farms. Therefore GHD recommends adopting the wording proposed in section 3.8.3 as that standard provides an appropriate balance between the costs imposed on generators in meeting the standard and the system security benefit delivered.

3.8.3 Recommended Wording

Clause 3.3.5.3

(a) For the purposes of this clause 3.3.5.3:

normal operating frequency band and abnormal operating frequency excursion band are references to the widest range specified for those terms for any condition (including an "island" condition) in the *frequency operating standards* that apply to the *region* in which the *generating unit* is located.

stabilisation *time* means the longest times allowable for the *frequency* of the *power system* to remain outside the normal operating frequency band, for any condition (including an "island" condition) in the *frequency operating standards* that apply to the *region* in which the *generating unit* is located. The stabilisation time is 10 minutes.

transient frequency limit and transient frequency time mean the values of 45 Hz and 2 seconds respectively, or such other values determined by the *Power System Controller*.

(b) The *automatic access standard* is a generating system and each of its generating units must be capable of continuous uninterrupted operation for frequencies in the following ranges:

(1) the lower bound of the transient frequency limit for at least 2 seconds;

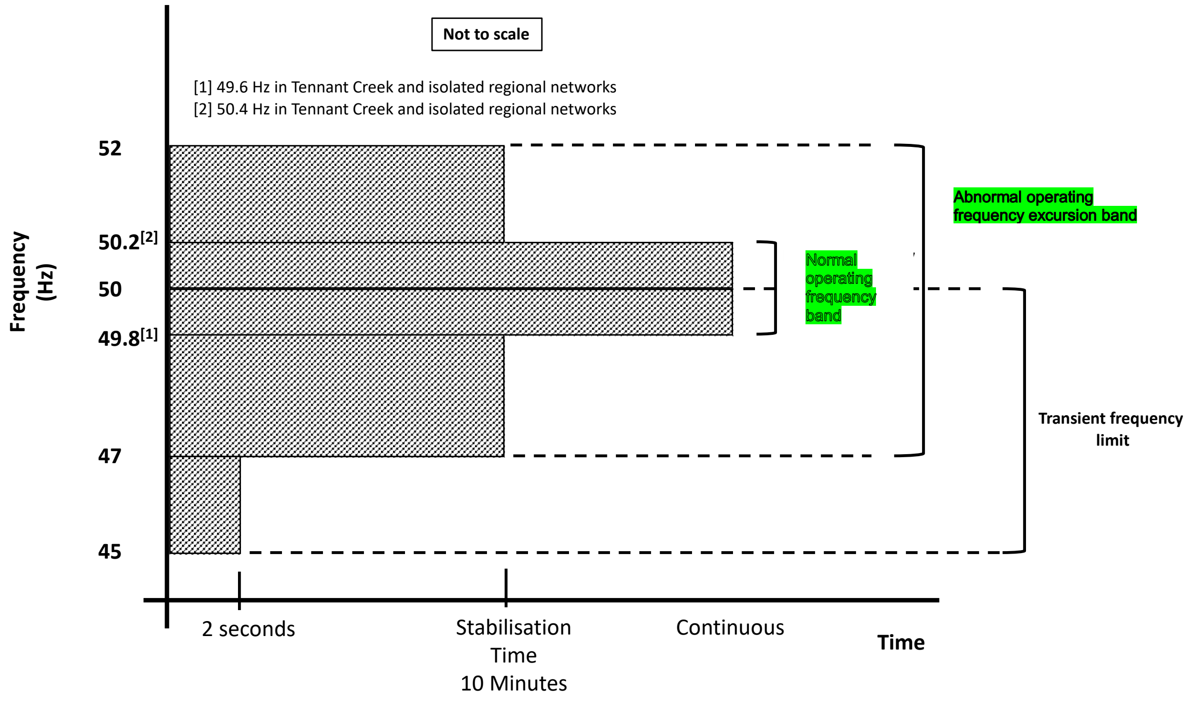
(2) the lower bound of the limits of the abnormal operating frequency excursion band specified in 2.2.2(b) to the lower bound of the *normal operating frequency band* for at least the stabilisation time;

(3) *the normal operating frequency band* for an indefinite period;

(4) the upper bound of the *normal operating frequency band* to the upper bound of the abnormal operating frequency excursion band for at least the stabilisation time,

unless the *rate of change of frequency* is outside the range of –4 Hz to 4 Hz per second.

The automatic access standard is illustrated in the following diagram reflecting the frequency standards outlined in clauses 2.2.1 and 2.2.2.



3.9 NTC Clause 3.3.5.4 – Generating System Response to Voltage Disturbances

3.9.1 Wording proposed by PWC

(a) The automatic access standard is a *generating system* and each of its *generating units* must be capable of continuous uninterrupted operation where a power system disturbance causes the voltage at the connection point to vary within the following ranges:

(1) over 130% of normal voltage for a period of at least 0.02 seconds after T(ov);

(2) 125% to 130% of normal voltage for a period of at least 0.2 seconds after T(ov);

(3) 120% to 125% of normal voltage for a period of at least 2.0 seconds after T(ov);

(4) 115% to 120% of normal voltage for a period of at least 20.0 seconds after T(ov);

(5) 110% to 115% of normal voltage for a period of at least 20 minutes after T(ov);

(6) 90% to 110% of normal voltage continuously;

(7) 80% to 90% of normal voltage for a period of at least 10 seconds after T(uv); and

(8) 70% to 80% of normal voltage for a period of at least 2 seconds after T(uv),

where T(ov) means a point in time when the voltage at the connection point first varied above 110% of normal voltage before returning to between 90% and 110% of normal voltage, and T(uv) means a point in time when the voltage at the connection point first varied below 90% of normal voltage before returning to between 90% and 110% of normal voltage.

(b) The access standard must include any operational arrangements necessary to ensure the *generating system* and each of its *generating units* will meet its agreed performance levels under abnormal *network* or *generating system* conditions.

3.9.2 Observations and Issues Identified

In this clause the performance levels are specified with reference to the normal voltage, however that term is not defined in the NTC. GHD recommends that the NER NT definition be adopted (with appropriate wording to reflect the terminology used in the NTC):

"In respect of a connection point, its nominal voltage or such other voltage up to 10% higher or lower than nominal voltage, as approved by the *Network Operator*, for that connection point."

The wording proposed by PWC reflects the automatic access standard specified in the NER NT. The review completed by the AEMC found that the over and under voltage levels specified in the automatic access standard were unlikely to impose significant costs on generators. The overvoltage levels being consistent with those adopted in a number of jurisdictions around the world. GHD notes that if the cost of meeting the voltage ride through requirements specified in the proposed access standard threaten the commercial feasibility of a generation development the negotiating framework specified in NTC clause 3.3.5 allows for potential negotiation of a lower standard. GHD is therefore satisfied that the access standard proposed by PWC with the revisions recommended by GHD provide an appropriate balance between costs imposed on generators in meeting the standard and the system security benefit delivered. It is recommended that the wording proposed in section 3.9.3 be adopted.

3.9.3 Recommended Wording

Clause 3.3.5.4

There are no recommended changes to the wording of the clause only key words need to be italicised. The clause will now read as follows.

(a) The automatic access standard is a *generating system* and each of its *generating units* must be capable of continuous uninterrupted operation where a power system disturbance causes the voltage at the connection point to vary within the following ranges:

(1) over 130% of *normal voltage* for a period of at least 0.02 seconds after T(ov);

(2) 125% to 130% of *normal voltage* for a period of at least 0.2 seconds after T(ov);

(3) 120% to 125% of *normal voltage* for a period of at least 2.0 seconds after T(ov);

(4) 115% to 120% of *normal voltage* for a period of at least 20.0 seconds after T(ov);

(5) 110% to 115% of *normal voltage* for a period of at least 20 minutes after T(ov);

(6) 90% to 110% of *normal voltage* continuously;

(7) 80% to 90% of *normal voltage* for a period of at least 10 seconds after T(uv); and

(8) 70% to 80% of *normal voltage* for a period of at least 2 seconds after T(uv),

where T(ov) means a point in time when the *voltage* at the *connection point* first varied above 110% of *normal voltage* before returning to between 90% and 110% of normal voltage, and T(uv) means a point in time when the *voltage* at the *connection point* first varied below 90% of *normal voltage* before returning to between 90% and 110% of *normal voltage*.

(b) The *access standard* must include any operational arrangements necessary to ensure the *generating system* and each of its *generating units* will meet its agreed performance levels under abnormal network or generating system conditions.

The following definition needs to be added to the glossary of terms in Attachment 1 of the NTC:

normal voltage

In respect of a connection point, its nominal voltage or such other voltage up to 10% higher or lower than nominal voltage, as approved by the *Network Operator*, for that connection point.

3.10 NTC Clause 3.3.5.5 – Generating System Response to Disturbances following Contingency Events

3.10.1 Wording proposed by PWC

(a) In this clause 3.3.5.5 a fault includes a fault of the relevant type having a metallic conducting path.

(b) The automatic access standard is:

(1) for a *generating system* and each of its *generating units*, the requirements of paragraphs (c) and (d);

(2) for a generating system comprised solely of synchronous generating units, the requirements of paragraph (e);

(3) for a *generating system* comprised solely of asynchronous generating units, the requirements of paragraphs (f) to (i); and

(4) for a *generating system* comprised of synchronous *generating units* and asynchronous *generating units*:

(i) for that part of the *generating system* comprised of *synchronous generating units*, the requirements of paragraph (e); and

(ii) for that part of the *generating system* comprised of asynchronous *generating units*, the requirements of paragraphs (f) to (i).

All generating systems

(c) A *generating system* and each of its *generating units* must remain in continuous uninterrupted operation for any disturbance caused by:

(1) a credible contingency event;

(2) a three phase fault in a transmission system cleared by all relevant primary protection systems;

(3) a two phase to ground, phase to phase or phase to ground fault in a transmission system cleared in:

(i) the longest time expected to be taken for a relevant breaker fail protection system to clear the fault; or

(ii) if a protection system referred to in subparagraph (i) is not installed, the greater of the time specified in clause 2.9.4 Table 5 (or if none is specified, 450 milliseconds) and the longest time expected to be taken for all relevant primary protection systems to clear the fault; or

(4) a three phase, two phase to ground, phase to phase or phase to ground fault in a distribution network cleared in:

(i) the longest time expected to be taken for the breaker fail protection system to clear the fault; or

(ii) if a protection system referred to in subparagraph (i) is not installed, the greater of 1500 milliseconds and the longest time expected to be taken for all relevant primary protection systems to clear the fault,

provided that the event is not one that would disconnect the generating unit from the power system by removing network elements from service.

(d) A *generating system* and each of its *generating units* must remain in continuous uninterrupted operation for a series of up to 15 disturbances within any five minute period caused by any combination of the events described in paragraph (c) where:

(1) up to six of the disturbances cause the *voltage* at the *connection point* to drop below 50% of *normal voltage*;

(2) in parts of the *network* where three-phase automatic reclosure is permitted, up to two of the disturbances are three phase faults, and otherwise, up to one three phase fault where *voltage* at the *connection point* drops below 50% of *normal voltage*;

(3) up to one disturbance is cleared by a *breaker fail protection system* or similar back-up *protection system*;

(4) up to one disturbance causes the *voltage* at the *connection point* to vary within the ranges under clause 3.3.5.4(a)(7) and (a)(8);

(5) the minimum clearance from the end of one disturbance and commencement of the next disturbance may be zero milliseconds; and

(6) all remaining disturbances are caused by faults other than three phase faults,

provided that none of the events would result in:

(7) the islanding of the *generating system* or cause a material reduction in power transfer capability by removing network elements from service.

Synchronous generating systems

(e) Subject to any changed power system conditions or energy source availability beyond the *Generator's* reasonable control, a *generating system* comprised of *synchronous generating units,* in respect of the types of fault described in subparagraphs (c)(2) to (4), must supply to or absorb from the *network*:

(1) to assist the maintenance of power system voltages during the fault, capacitive reactive current of at least the greater of its pre-disturbance reactive current and 4% of the maximum continuous current of the generating system including all operating synchronous *generating units* (in the absence of a disturbance) for each 1% reduction (from the level existing just prior to the fault) of *connection point* voltage during the fault;

(2) after clearance of the fault, reactive power sufficient to ensure that the *connection point* voltage is within the range for continuous uninterrupted operation under clause 3.3.5.4; and

(3) from 100 milliseconds after clearance of the fault, active power of at least 95% of the level existing just prior to the fault.

Asynchronous Generating Systems

(f) Subject to any changed power system conditions or energy source availability beyond the *Generator's* reasonable control, a *generating system* comprised of asynchronous *generating units*, in respect of the types of fault described in subparagraphs (c)(2) to (4), must have facilities capable of supplying to or absorbing from the network:

(1) to assist the maintenance of power system voltages during the fault:

(i) capacitive reactive current in addition to its pre-disturbance level of at least 4% of the maximum continuous current of the *generating system* including all operating asynchronous *generating units* (in the absence of a disturbance) for each 1% reduction of voltage at the connection point below the relevant range in which a reactive current response must commence, as identified in subparagraph (g)(1), with the performance standards to record the required response agreed with the *Network Operator* and *Power System Controller*; and

(ii) inductive reactive current in addition to its pre-disturbance level of at least 6% of the maximum continuous current of the generating system including all operating asynchronous *generating units* (in the absence of a disturbance) for each 1% increase of voltage at the connection point above the relevant range in which a reactive current response must commence, as identified in subparagraph (g)(1), with the performance standards to record the required response agreed with the *Network Operator* and *Power System Controller*,

during the disturbance and maintained until connection point voltage recovers to between 90% and 110% of normal voltage, or such other range agreed with the *Network Operator* and *Power System Controller*, except for voltages below the relevant threshold identified in paragraph (h); and

(2) from 100 milliseconds after clearance of the fault, active power of at least 95% of the level existing just prior to the fault.

(g) For the purpose of paragraph (f):

(1) the *generating system* must commence a response when the voltage is in an under-voltage range of 85% to 90% or an over-voltage range of 110% to 115% of normal voltage. These ranges may be varied with the agreement of the *Network Operator* and *Power System Controller* (provided the magnitude of the range between the upper and lower bounds remains at Δ5%); and

(2) the reactive current response must have a rise time of no greater than 40 milliseconds and a settling time of no greater than 70 milliseconds and must be adequately damped.

(h) Despite paragraph (f), a generating system is not required to provide a capacitive reactive current response in accordance with subparagraph (f)(1)(i) where:

(1) the *generating system* is directly connected to the power system with no step-up or connection transformer; and

(2) voltage at the *connection point* is 5% or lower of normal voltage.

(i) Subject to paragraph (h), despite the amount of reactive current injected or absorbed during voltage disturbances, and subject to thermal limitations and energy source availability, a *generating system* must make available at all times:

(1) sufficient current to maintain rated apparent power of the *generating system* including all operating *generating units* (in the absence of a disturbance), for all *connection point* voltages above 115% (or otherwise, above the over-voltage range agreed in accordance with subparagraph (g)(1)); and

(2) the maximum continuous current of the *generating system* including all operating *generating units* (in the absence of a disturbance) for all *connection point* voltages below 85% (or otherwise, below the under-voltage range agreed in accordance with subparagraph (g)(1)),

except that the *Network Operator* and *Power System Controller* may agree limits on active current injection where required to maintain power system security and/or the quality of supply to other *Network Users*.

General requirement

All generating systems

(j) The performance standard must include any operational arrangements to ensure the *generating system* including all operating *generating units* will meet its agreed performance levels under abnormal network or *generating system* conditions.

(k) When assessing multiple disturbances, a fault that is re-established following operation of automatic reclose equipment shall be counted as a separate disturbance.

Asynchronous generating systems

(l) For the purpose of paragraph (f):

(1) the reactive current contribution may be limited to the maximum continuous current of a *generating system*, including its operating asynchronous *generating units*;

(2) the reactive current contribution and *voltage* deviation described may be measured at a location other than the *connection point* (including within the relevant *generating system*) where agreed with the *Network Operator* and *Power System Controller*, in which case the level of injection and absorption will be assessed at that agreed location;

(3) the reactive current contribution required may be calculated using phase to phase, phase to ground or sequence components of *voltages*. The ratio of the negative sequence to positive sequence components of the reactive current contribution must be agreed with the *Network Operator* and *Power System Controller* for the types of disturbances listed in this clause 3.3.5.5; and

(4) the performance standards must record all conditions (which may include temperature) considered relevant by the *Network Operator* and *Power System Controller* under which the reactive current response is required.

Synchronous generating systems and units

(m) For a *generating system* comprised solely of synchronous *generating units*, the reactive current contribution may be limited to 250% of the maximum continuous current of the *generating system*.

(n) For a synchronous *generating unit* within a *generating system* (other than a *generating system* described in paragraph (m)), the reactive current contribution may be limited to 250% of the maximum continuous current of that synchronous *generating unit*.

3.10.2 Observations and Issues Identified

In this clause the performance levels are specified with reference to maintaining continuous uninterrupted operation, but that term is not defined, creating ambiguity. GHD recommends that the NER NT definition for continuous uninterrupted operation be adopted:

In respect of a generating system or generating unit operating immediately prior to a power system disturbance:

a) *not disconnecting from the power system except under its performance standards established under clauses S5.2.5.8 and S5.2.5.9;*

b) *during the disturbance contributing active and reactive current as required by its performance standards established under clause S5.2.5.5;*

c) *after clearance of any electrical fault that caused the disturbance, only substantially varying its active power and reactive power as required or permitted by its performance standards established under clauses S5.2.5.5, S5.2.5.11, S5.2.5.13 and S5.2.5.14; and*

d) *not exacerbating or prolonging the disturbance or causing a subsequent disturbance for other connected plant, except as required or permitted by its performance standards,*

with all essential auxiliary and reactive plant remaining in service.

Cumulative time thresholds from NER NT are missing which creates an unrealistic expectation of generator performance. A worst case interpretation may require generators to ride through 15 faults resulting in near zero voltage at the connection point for 5 minutes. This is likely to be challenging for generators to meet. Adopting a framework similar to the following provisions specified in the automatic access standard in the NER NT should be considered:

(8) *the cumulative time that voltage at the connection point is lower than 90% of normal voltage exceeding 1,800 milliseconds within any five minute period; or*

(9) *the time integral, within any five minute period, of the difference between 90% of normal voltage and the voltage at the connection point when the voltage at the connection point is lower than 90% of normal voltage exceeding 1 pu second.*

It is recognised that the NT experiences a high level of lightning activity than many regions of the NEM and it may therefore be appropriate for the cumulative thresholds to be varied from those in the NER NT which reflect those specified in the NER. However omitting any cumulative thresholds is not recommended as this may result in unrealistic or very expensive performance requirements. This position is supported by findings published by the AEMC[3] in their final report on the generator technical performance standards rule change. The AEMC found that:

- *"the automatic access standard requirements was more arduous than the international jurisdictions considered, but noted that generator access standards in the NER are relatively unique compared to international standards in providing a negotiation range between different levels of performance." and*
- *"as part of the manufacturer survey, four out of five respondents (including manufacturers of both synchronous and asynchronous generating systems and units) claimed that their equipment could readily meet the updated minimum access standard (i.e. at little or no additional cost using 'off-the-shelf' equipment), and five out of six respondents claimed that their equipment could readily meet, or meet with modification (i.e. a likely material, but manageable additional cost), the updated automatic access standard.*

The term "transmission system" requires definition.

[3] AEMC final report, page 212, https://www.aemc.gov.au/sites/default/files/2018-09/Final%20Determination_0.pdf

“Table 5” in NTC clause 2.9.4 does not exist and this reference should be updated to “Figure 5”.

Protection clearing times referenced are different to those in the NER NT but align with system standards in the clause 2.9.4 of the NTC and are therefore appropriate.

The rest of the wording proposed by PWC reflects the automatic access standard specified in the NER NT. The review completed by the AEMC identified that the automatic access standard is higher than the standard normally specified in other jurisdictions and may in some cases impose additional but manageable costs on generators. GHD notes that if those costs threaten the commercial feasibility of a generation development the proposed negotiating framework specified in NTC clause 3.3.5 allows for potential negotiation of a lower standard. GHD is therefore satisfied that the access standard proposed by PWC with the revisions recommended by GHD provide an appropriate balance between costs imposed on generators in meeting the standard and the system security benefit delivered. It is recommended that the wording proposed in section 3.10.3 be adopted.

3.10.3 Recommended Wording

Clause 3.3.5.5

(a) In this clause 3.3.5.5 a fault includes a fault of the relevant type having a metallic conducting path.

(b) The automatic access standard is:

(1) for a *generating system* and each of its *generating units*, the requirements of paragraphs (c) and (d);

(2) for a generating system comprised solely of synchronous generating units, the requirements of paragraph (e);

(3) for a generating system comprised solely of asynchronous generating units, the requirements of paragraphs (f) to (i); and

(4) for a generating system comprised of synchronous generating units and asynchronous generating units:

(i) for that part of the *generating system* comprised of *synchronous generating units*, the requirements of paragraph (e); and

(ii) for that part of the generating system comprised of asynchronous generating units, the requirements of paragraphs (f) to (i).

All generating systems

(c) A generating system and each of its generating units must remain in continuous uninterrupted operation for any disturbance caused by:

(1) a credible contingency event;

(2) a three phase fault in a transmission system cleared by all relevant primary protection systems;

(3) a two phase to ground, phase to phase or phase to ground fault in a transmission system cleared in:

(i) the longest time expected to be taken for a relevant breaker fail protection system to clear the fault; or

(ii) if a protection system referred to in subparagraph (i) is not installed, the greater of the time specified in clause 2.9.4 Figure 5 (or if none is specified, 450 milliseconds) and the longest time expected to be taken for all relevant primary protection systems to clear the fault; or

(4) a three phase, two phase to ground, phase to phase or phase to ground fault in a distribution network cleared in:

(i) the longest time expected to be taken for the breaker fail protection system to clear the fault; or

(ii) if a protection system referred to in subparagraph (i) is not installed, the greater of 1500 milliseconds and the longest time expected to be taken for all relevant primary protection systems to clear the fault,

provided that the event is not one that would disconnect the generating unit from the power system by removing network elements from service.

(d) A generating system and each of its generating units must remain in continuous uninterrupted operation for a series of up to 15 disturbances within any five minute period caused by any combination of the events described in paragraph (c) where:

(1) up to six of the disturbances cause the *voltage* at the *connection point* to drop below 50% of *normal voltage*;

(2) in parts of the *network* where three-phase automatic reclosure is permitted, up to two of the disturbances are three phase faults, and otherwise, up to one three phase fault where *voltage* at the *connection point* drops below 50% of *normal voltage*;

(3) up to one disturbance is cleared by a *breaker fail protection system* or similar back-up *protection system*;

(4) up to one disturbance causes the *voltage* at the *connection point* to vary within the ranges under clause 3.3.5.4(a)(7) and (a)(8);

(5) the minimum clearance from the end of one disturbance and commencement of the next disturbance may be zero milliseconds; and

(6) all remaining disturbances are caused by faults other than three phase faults,

provided that none of the events would result in:

(7) the islanding of the generating system or cause a material reduction in power transfer capability by removing network elements from service.

(8) the cumulative time that voltage at the connection point is lower than 90% of normal voltage exceeding 1,800 milliseconds within any five minute period; or

(9) the time integral, within any five minute period, of the difference between 90% of normal voltage and the voltage at the connection point when the voltage at the connection point is lower than 90% of normal voltage exceeding 1 pu second.

Synchronous generating systems

(e) Subject to any changed power system conditions or energy source availability beyond the Generator’s reasonable control, a generating system comprised of synchronous generating units, in respect of the types of fault described in subparagraphs (c)(2) to (4), must supply to or absorb from the network:

(1) to assist the maintenance of power system voltages during the fault, capacitive reactive current of at least the greater of its pre-disturbance reactive current and 4% of the maximum continuous current of the generating system including all operating synchronous *generating units* (in the absence of a disturbance) for each 1% reduction (from the level existing just prior to the fault) of *connection point* voltage during the fault;

(2) after clearance of the fault, reactive power sufficient to ensure that the *connection point* voltage is within the range for continuous uninterrupted operation under clause 3.3.5.4; and

(3) from 100 milliseconds after clearance of the fault, active power of at least 95% of the level existing just prior to the fault.

Asynchronous Generating Systems

(f) Subject to any changed power system conditions or energy source availability beyond the Generator’s reasonable control, a generating system comprised of asynchronous generating units, in respect of the types of fault described in subparagraphs (c)(2) to (4), must have facilities capable of supplying to or absorbing from the network:

(1) to assist the maintenance of power system voltages during the fault:

(i) capacitive reactive current in addition to its pre-disturbance level of at least 4% of the maximum continuous current of the *generating system* including all operating asynchronous *generating units* (in the absence of a disturbance) for each 1% reduction of voltage at the connection point below the relevant range in which a reactive current response must commence, as identified in subparagraph (g)(1), with the performance standards to record the required response agreed with the *Network Operator* and *Power System Controller*; and

(ii) inductive reactive current in addition to its pre-disturbance level of at least 6% of the maximum continuous current of the generating system including all operating asynchronous *generating units* (in the absence of a disturbance) for each 1% increase of voltage at the connection point above the relevant range in which a reactive current response must commence, as identified in subparagraph (g)(1), with the performance standards to record the required response agreed with the *Network Operator* and *Power System Controller*,

during the disturbance and maintained until connection point voltage recovers to between 90% and 110% of normal voltage, or such other range agreed with the *Network Operator* and *Power System Controller*, except for voltages below the relevant threshold identified in paragraph (h); and

(2) from 100 milliseconds after clearance of the fault, active power of at least 95% of the level existing just prior to the fault.

(g) For the purpose of paragraph (f):

(1) the generating system must commence a response when the voltage is in an under-voltage range of 85% to 90% or an over-voltage range of 110% to 115% of normal voltage. These ranges may be varied with the agreement of the Network Operator and Power System Controller (provided the magnitude of the range between the upper and lower bounds remains at Δ5%); and

(2) the reactive current response must have a rise time of no greater than 40 milliseconds and a settling time of no greater than 70 milliseconds and must be adequately damped.

(h) Despite paragraph (f), a generating system is not required to provide a capacitive reactive current response in accordance with subparagraph (f)(1)(i) where:

(1) the *generating system* is directly connected to the power system with no step-up or connection transformer; and

(2) voltage at the *connection point* is 5% or lower of normal voltage.

(i) Subject to paragraph (h), despite the amount of reactive current injected or absorbed during voltage disturbances, and subject to thermal limitations and energy source availability, a generating system must make available at all times:

(1) sufficient current to maintain rated apparent power of the *generating system* including all operating *generating units* (in the absence of a disturbance), for all *connection point* voltages above 115% (or otherwise, above the over-voltage range agreed in accordance with subparagraph (g)(1)); and

(2) the maximum continuous current of the *generating system* including all operating *generating units* (in the absence of a disturbance) for all *connection point* voltages below 85% (or otherwise, below the under-voltage range agreed in accordance with subparagraph (g)(1)),

except that the *Network Operator* and *Power System Controller* may agree limits on active current injection where required to maintain power system security and/or the quality of supply to other *Network Users*.

General requirement

All generating systems

(j) The performance standard must include any operational arrangements to ensure the generating system including all operating generating units will meet its agreed performance levels under abnormal network or generating system conditions.

(k) When assessing multiple disturbances, a fault that is re-established following operation of automatic reclose equipment shall be counted as a separate disturbance.

Asynchronous generating systems

(l) For the purpose of paragraph (f):

(1) the reactive current contribution may be limited to the maximum continuous current of a *generating system*, including its operating asynchronous *generating units*;

(2) the reactive current contribution and *voltage* deviation described may be measured at a location other than the *connection point* (including within the relevant *generating system*) where agreed with the *Network Operator* and *Power System Controller*, in which case the level of injection and absorption will be assessed at that agreed location;

(3) the reactive current contribution required may be calculated using phase to phase, phase to ground or sequence components of *voltages*. The ratio of the negative sequence to positive sequence components of the reactive current contribution must be agreed with the *Network Operator* and *Power System Controller* for the types of disturbances listed in this clause 3.3.5.5; and

(4) the performance standards must record all conditions (which may include temperature) considered relevant by the *Network Operator* and *Power System Controller* under which the reactive current response is required.

Synchronous generating systems and units

(m) For a generating system comprised solely of synchronous generating units, the reactive current contribution may be limited to 250% of the maximum continuous current of the generating system.

(n) For a synchronous generating unit within a generating system (other than a generating system described in paragraph (m)), the reactive current contribution may be limited to 250% of the maximum continuous current of that synchronous generating unit.

The following definitions need to be added to the glossary of terms in Attachment 1 of the NTC:

continuous uninterrupted operation

In respect of a generating system or generating unit operating immediately prior to a power system disturbance:

(a) not disconnecting from the power system except under its performance standards established under clauses 3.3.5.8 and 3.3.5.9;

(b) during the disturbance contributing active and reactive current as required by its performance standards established under clause 3.3.5.5;

(c) after clearance of any electrical fault that caused the disturbance, only substantially varying its active power and reactive power as required or permitted by its performance standards established under clauses 3.3.5.5, 3.3.5.11, 3.3.5.13 and 3.3.5.14; and

(d) not exacerbating or prolonging the disturbance or causing a subsequent disturbance for other connected plant, except as required or permitted by its performance standards,

with all essential auxiliary and reactive plant remaining in service.

transmission system

> A *transmission network*, together with the *connection assets* associated with the *transmission network*, which is *connected* to another *transmission* or *distribution system*.

3.11 NTC Clause 3.3.5.6 – Quality of Electricity Generated and Continuous Uninterrupted Operation

3.11.1 Wording proposed by PWC

> The automatic access standard is a generating system including each of its operating generating units and reactive plant, must not disconnect from the power system as a result of voltage fluctuation, harmonic voltage distortion and voltage unbalance conditions at the connection point within the levels specified in clauses 2.4.1, 2.4.2 and 2.4.3.

3.11.2 Observations and Issues Identified

In this clause the proposed revisions to the NTC introduce an automatic access standard that is equivalent to the minimum standard in the NER NT. The NER NT expects the minimum standard is achieved in all cases, limiting scope for negotiation.

The drafting in the NTC suggests the opportunity to negotiate a lower level of performance might exist. While the potential exists for generators to seek to negotiate access levels lower than the automatic, it is unlikely that generators will find it difficult or expensive to comply with this automatic access standard and are therefore unlikely to try to negotiate a lower access standard. GHD is satisfied that the access standard proposed by PWC provides an appropriate balance between costs imposed on generators in meeting the standards and the system security benefit delivered. GHD therefore recommends no change to the wording proposed by PWC.

3.12 NTC Clause 3.3.5.7 – Partial Load Rejection

3.12.1 Wording proposed by PWC

> The automatic access standard is a generating system shall be capable of continuous uninterrupted operation, during and following a load reduction which occurs in less than 0.5 seconds, from a fully or partially loaded condition provided that the load reduction is less than 50% of the generating system's nameplate rating and the load remains above minimum load or as otherwise agreed between the Network Operator and the relevant User and stated in the connection agreement between them.

3.12.2 Observations and Issues Identified

In this clause the proposed revisions to the NTC introduce an automatic access standard that is more onerous than that specified in the NER NT in terms of the size of load rejection (50% vs 30%) and the duration over which the load rejection occurs (0.5s vs 10s).

The proposed drafting is consistent with the higher RoCoF ride through limit of 4Hz/s and the more aggressive droop response specified in NTC 3.3.5.11.

GHD considers that the wording proposed by PWC is appropriate given the NT power systems lack interconnection to stronger networks and are expecting to experience connection of significant levels of asynchronous generation offering little inertia.

GHD is satisfied that the access standard proposed by PWC provides an appropriate balance between costs imposed on generators in meeting the standards and the system security benefit delivered. GHD therefore recommends the wording in section 3.12.3 be adopted. No wording changes are recommended. Some formatting changes are recommended to correctly italicise terms.

3.12.3 Recommended Wording

Clause 3.3.5.7

The *automatic access standard* is a *generating system* shall be capable of *continuous uninterrupted operation,* during and following a load reduction which occurs in less than 0.5 seconds, from a fully or partially loaded condition provided that the load reduction is less than 50% of the generating system's *nameplate rating* and the load remains above minimum load or as otherwise agreed between the Network Operator and the relevant User and stated in the *connection agreement* between them.

3.13 NTC Clause 3.3.5.8 – Protection of Generating Units from Power System Disturbances

3.13.1 Wording proposed by PWC

(1) Protection of Generating Units from Power System Disturbances

(a) The automatic access standard is:

(1) subject to paragraph (d), for a *generating system* or any of its *generating units* that is required by a *Generator* or *Network Operator* to be automatically disconnected from the power system in response to abnormal conditions arising from the power system, the relevant protection system or control system must not disconnect the *generating system* for:

(i) conditions for which it must remain in continuous uninterrupted operation; or

(ii) conditions it must withstand under this Code.

(b) The *Network Operator* or *Power System Controller* may require that an access standard include a requirement for the *generating system* to be automatically disconnected by a local or remote control scheme whenever the part of the network to which it is connected has been disconnected, forming an island that supplies a *customer*.

(c) The access standard must include specification of conditions for which the *generating unit* or *generating system* must trip and must not trip.

(d) Notwithstanding clauses 3.3.5.3, 3.3.5.4, 3.3.5.5, 3.3.5.6 and 3.3.5.7, a *generating system* may be automatically disconnected from the power system under any of the following conditions:

(1) in accordance with an *ancillary services agreement* between the *Generator* and the *Network Operator* or *Power System Controller*;

(2) where a load that is not part of the *generating system* has the same *connection point* as the *generating system* and the *Network Operator* and *Power System Controller* agree that the disconnection would in effect be under-frequency load shedding;

(3) where the *generating system* is automatically disconnected under paragraph (a), clause 3.3.5.9 or by an emergency frequency control scheme;

(4) where the *generating system* is automatically disconnected under clause 3.3.5.10; or

(5) in accordance with an agreement between the *Generator* and the *Network Operator* (including an agreement in relation to an emergency control scheme under clause 2.6 to provide a service that is necessary to maintain or restore power system security in the event of a specified contingency event.)

(e) The *Network Operator* or *Power System Controller* is not liable for any loss or damage incurred by the *Generator* or any other person as a consequence of a fault on either the power system, or within the *Generator's facility*.

3.13.2 Observations and Issues Identified

The wording proposed by PWC introduces an automatic access standard while the NER NT specifies only a minimum access standard. The automatic access standard proposed by PWC is set at the same level as the minimum access standard in the NER NT. The lack of a minimum standard in the proposed revisions to the NTC, suggests lower than automatic may be acceptable, potentially creating ambiguity as discussed for 3.3.5.6. As with 3.3.5.6 GHD is satisfied that generators can normally achieve the level of access specified for the automatic access standard and are therefore unlikely to pursue a lower standard. We therefore have not recommended any change to the wording suggested by PWC except for those points noted below.

The NER NT requires all generators >30MW to rapidly reduce output by at least half if required to control over-frequency events. This is missing from the wording proposed by PWC for this clause. The over-frequency control of generators would be of high value for NT power systems while at the same time adding this requirement to the GPS would not add significant additional costs to generator development. It is therefore recommended that the provision be added into the NTC. The 30 MW threshold is not appropriate for the NT power systems, 30 MW is the threshold applied in the NEM. Given the much smaller size of the NT power systems GHD recommends the threshold be removed which will mean that the requirement applies to all generators that are large enough to have a GPS.

The reference to emergency control schemes under NTC clause 2.6 is incorrect as clause 2.6 deals with stability. NTC clause 3.2.1.5 allows for the network operator to require the installation of emergency controls and would be a more appropriate reference.

GHD is satisfied that the access standard proposed by PWC with the recommended revision is appropriate as it provides an appropriate balance between costs imposed on generators in meeting the standards and the system security benefit delivered. GHD therefore recommends the wording in section 3.13.3 be adopted

3.13.3 Recommended Wording

Clause 3.3.5.8

(1) Protection of Generating Units from Power System Disturbances

(a) The automatic access standard is:

(1) subject to paragraph (d), for a *generating system* or any of its *generating units* that is required by a *Generator* or *Network Operator* to be automatically disconnected from the power system in response to abnormal conditions arising from the power system, the relevant protection system or control system must not disconnect the *generating system* for:

(i) conditions for which it must remain in continuous uninterrupted operation; or

(ii) conditions it must withstand under this Code.

(2) a *generating system*, connected to a *network* must have facilities to automatically and rapidly reduce its generation:

(i) by at least half, if the frequency at the *connection point* exceeds a level nominated by the *Network Operator* (not less than the upper limit of the *operational frequency tolerance band*) and the duration above this *frequency* exceeds a value nominated by the *Network Operator* where the reduction may be achieved:

(A) by reducing the output of the *generating system* within 3 seconds, and holding the output at the reduced level until the *frequency* returns to within the *normal operating frequency band*; or

(B) by disconnecting the *generating system* from the *power system* within 1 second; or

(ii) in proportion to the difference between the *frequency* at the *connection point* and a level nominated by the *Network Operator* (not less than the upper limit of the *operational frequency tolerance band*), such that the generation is reduced by at least half, within 3 seconds of the *frequency* reaching the upper limit of the *operational frequency tolerance band*.

(b) The Network Operator or Power System Controller may require that an access standard include a requirement for the generating system to be automatically disconnected by a local or remote control scheme whenever the part of the network to which it is connected has been disconnected, forming an island that supplies a customer.

(c) The access standard must include specification of conditions for which the generating unit or generating system must trip and must not trip.

(d) Notwithstanding clauses 3.3.5.3, 3.3.5.4, 3.3.5.5, 3.3.5.6 and 3.3.5.7, a generating system may be automatically disconnected from the power system under any of the following conditions:

(3) in accordance with an ancillary services agreement between the Generator and the Network Operator or Power System Controller;

(4) where a load that is not part of the generating system has the same connection point as the generating system and the Network Operator and Power System Controller agree that the disconnection would in effect be under-frequency load shedding;

(5) where the generating system is automatically disconnected under paragraph (a), clause 3.3.5.9 or by an emergency frequency control scheme;

(6) where the generating system is automatically disconnected under clause 3.3.5.10; or

(7) in accordance with an agreement between the Generator and the Network Operator (including an agreement in relation to an emergency control scheme under clause 3.2.1.5 to provide a service that is necessary to maintain or restore power system security in the event of a specified contingency event.)

(e) The Network Operator or Power System Controller is not liable for any loss or damage incurred by the Generator or any other person as a consequence of a fault on either the power system, or within the Generator's facility.

The following definition need to be added to the glossary of terms in Attachment 1 of the NTC:

generating system

a system comprising one or more *generating units* and includes auxiliary or *reactive plant* that is located on the *Generator's* side of the *connection point* and is necessary for the *generating system* to meet its performance obligations.

operational frequency tolerance band

The range of *frequency* within which the power system is to be operated under abnormal operating conditions as specified in clause 2.2.2 (b)

3.14 NTC Clause 3.3.5.9 – Protection Systems that Impact on Power System Security

3.14.1 Wording proposed by PWC

(a) The automatic access standard is:

(1) primary protection systems must be provided to disconnect from the power system any faulted element in a *generating system* and in protection zones that include the connection point within the applicable fault clearance time determined under clause 2.9.4 and 2.9.5;

(2) each primary protection system must have sufficient redundancy to ensure that a faulted element within its protection zone is disconnected from the power system within the applicable fault clearance time with any single protection

element (including any communications facility upon which that protection system depends) out of service; and

(3) breaker fail protection systems must be provided to clear faults that are not cleared by the circuit breakers controlled by the primary protection system within the applicable fault clearance time determined under clause 2.9.4 and 2.9.5

(b) In relation to an automatic access standard under this clause 3.3.5.9, the *Generator* must provide redundancy in the primary protection systems under paragraph (a)(2) and provide breaker fail protection systems under paragraph (a)(3) if the *Network Operator* and *Power System Controller* consider that a lack of these facilities could result in:

(1) a material adverse impact on power system security or quality of supply to other *Network Users*; or

(2) a reduction in intra-regional power transfer capability,

through any mechanism including:

(3) consequential tripping of, or damage to, other network equipment or facilities of other *Network Users,* that would have a power system security impact; or

(4) instability that would not be detected by other protection systems in the network.

(c) The *Network Operator* and the *Generator* must cooperate in the design and implementation of protection systems to comply with this clause 3.3.5.9, including cooperation on:

(1) the use of current transformer and voltage transformer secondary circuits (or equivalent) of one party by the protection system of the other;

(2) tripping of one party's circuit breakers by a protection system of the other party; and

(3) co-ordination of protection system settings to ensure inter-operation.

(d) The protection system design referred to in paragraphs (a) must:

(1) be coordinated with other protection systems;

(2) avoid consequential disconnection of other *Network Users'* facilities; and

(3) take into account existing obligations of the *Network Operator* under *connection agreements* with other *Network Users*.

3.14.2 Observations and Issues Identified

The wording proposed by PWC is consistent with the automatic access standard in the NER NT with the exception that the specified fault clearing times in the proposed differ from those in the NER NT. GHD considers that the proposed fault clearing times are appropriate as they align with the NT system standards specified in sections 2.9.4 and 2.9.5 of the NTC.

The access standard proposed by PWC is reasonable as it reflects the level of access typically achieved by new generators connecting to the NEM, with clearing times adjusted to reflect those appropriate for NT power systems. Generators connecting to the NT power systems should be able to meet the proposed access standard. If this is not feasible the provision of clause 3.3.5 can be applied to negotiate a lower performance standard.

GHD is satisfied that the access standard proposed by PWC is appropriate as it provides an appropriate balance between costs imposed on generators in meeting the standards and the system security benefit delivered. GHD therefore does not recommend any additional change to the wording proposed by PWC.

3.15 NTC Clause 3.3.5.10 – Protection to Trip Plant for Unstable Operation

3.15.1 Wording proposed by PWC

(a) The automatic access standard is a generating system must have:

(1) for its synchronous generating units, a protection system to disconnect it promptly when a condition that would lead to pole slipping is detected, to prevent pole slipping or other conditions where a generating unit causes active power, reactive power or voltage at the connection point to become unstable as assessed in accordance with the power system stability guidelines established under clause 16; and

(2) for its asynchronous generating units, a protection system to disconnect it promptly for conditions where the active power, reactive power or voltage at the connection point becomes unstable as assessed in accordance with the guidelines for power system stability established under clause 16.

3.15.2 Observations and Issues Identified

The revisions proposed by PWC introduce a requirement for generator protection schemes to trip units that become unstable, with the assessment of stability informed by power system stability guidelines established under Clause 16. Clause 16 does not mention the establishment of any guidelines. Clause 16 is titled "Stability criteria". It is recommended the reference to guidelines be replaced with criteria.

The NER NT requires that power system stability guidelines are established in accordance with clause 4.3.4(h). However that clause does not exist in the NER NT. In the NEM AEMO is allocated the responsibility for producing power system stability guidelines via NER 4.3.4(h).

NER clause 4.3.4(h) states that AEMO must develop, and may amend, guidelines for power system stability but only in consultation with Registered Participants in accordance with the Rules consultation procedures, and must publish the guidelines for power system stability.

In all other respects the wording proposed by PWC reflects the automatic access standard in the NER NT. The access standard proposed by PWC is reasonable as it reflects the level of access typically achieved by new generators connecting to the NEM. The proposed standard can readily be met by generators and assists in maintaining stable operation of the power system.

GHD is satisfied that the access standard proposed by PWC with the recommended revision is appropriate as it provides an appropriate balance between costs imposed on generators in meeting the standards and the system security benefit delivered. GHD therefore recommends the wording in section 3.15.3 be adopted.

3.15.3 Recommended Wording

(a) The automatic access standard is a generating system must have:

(1) for its synchronous generating units, a protection system to disconnect it promptly when a condition that would lead to pole slipping is detected, to prevent pole slipping or other conditions where a generating unit causes active power, reactive power or voltage at the connection point to become unstable as assessed in accordance with the power system stability criteria established under clause 16; and

(2) for its asynchronous generating units, a protection system to disconnect it promptly for conditions where the active power, reactive power or voltage at the connection point becomes unstable as assessed in accordance with the guidelines for power system stability established under clause 16.

3.16 NTC Clause 3.3.5.11 – Frequency Control

3.16.1 Wording proposed by PWC

3.3.5.11 Frequency Control

(a) For the purpose of this clause 3.3.5.11:

Droop means, in relation to frequency response mode, the percentage change in power system frequency as measured at the connection point, divided by the percentage change in power transfer of the generating system expressed as a percentage of the maximum operating level of the generating system. Droop must be measured at frequencies that are outside the deadband and within the limits of power transfer.

(b) The automatic access standard is:

(1) a *generating system's* power transfer to the power system must not:

(i) increase in response to a rise in the frequency of the power system as measured at the connection point; or
(ii) decrease in response to a fall in the frequency of the power system as measured at the connection point; and

(2) a *generating system* must be capable of operating in frequency response mode such that it automatically provides a proportional:

(i) decrease in power transfer to the power system in response to a rise in the frequency of the power system as measured at the connection point; and

(ii) increase in power transfer to the power system in response to a fall in the frequency of the power system as measured at the connection point,

sufficiently rapidly and sustained for a sufficient period for the *Generator* to be in a position to offer measurable amounts of all ancillary services for the provision of power system frequency control.

(c) Each control system used to satisfy this clause 3.3.5.11 must be adequately damped.

(d) The amount of a relevant market ancillary service for which the plant may be registered must not exceed the amount that would be consistent with the performance standard registered in respect of this requirement.

(e) For the purposes of subparagraph (b)(2):

(1) the change in power transfer to the power system must occur with no delay beyond that required for stable operation, or inherent in the plant controls, once the frequency of the power system as measured at the connection point leaves a deadband around 50 Hz;

(2) a generating system must be capable of setting the deadband and droop within the following ranges:

(i) the deadband referred to in subparagraph (1) must be set within the range of 0 to ± 1.0 Hz. Different deadband settings may be applied for a rise or fall in the frequency of the power system as measured at the connection point; and

(ii) the droop must be settable within the range of 1% to 6%, or such other settings as agreed with the *Network Operator* and *Power System Controller*;

(3) nothing in subparagraph (b)(2) is taken to require a *generating system* to operate below its minimum operating level in response to a rise in the frequency of the power system as measured at the connection point, or above its maximum operating level in response to a fall in the frequency of the power system as measured at the connection point; and

(4) the performance standards must record:

(i) agreed values for maximum operating level and minimum operating level, and where relevant the method of determining the values, and the values for a generating system must take into account its in-service generating units; and

(ii) for the purpose of subparagraph (b)(2), the market ancillary services, including the performance parameters and requirements that apply to each such market ancillary service.

3.16.2 Observations and Issues Identified

For this clause the proposed revisions to the NTC introduce frequency control requirements defined with reference to the maximum and minimum operating level of a generating unit or generating system. These terms are defined in the NER NT but those definitions appear to be missing from the proposed change to the NTC. It is recommended that the definitions in the NER NT be included in the NTC.

There are two performance standards proposed by PWC that require generators to provide a capability to respond to a disturbance in system frequency. NTC clause 3.3.5.11 requires provision of frequency response similar to the capability typically provided by governing systems on thermal generators. NTC clause 3.3.5.15 requires a much quicker response, mirroring the inertia response and provided by synchronous generators to limit RoCoF and arrest the frequency change following load or generation contingencies. The control systems and settings installed by generators that respond to frequency deviations need to be designed to meet the requirements of both clauses.

The proposed wording for NTC clause 3.3.5.11 reflects requirements similar to the automatic access standard specified in the NER NT for frequency control. The proposed frequency control performance standard requires the provision of a frequency response capability defined by a droop response and dead band:

- The dead band must be settable with the range 0 to 1 Hz which although consistent with the NER NT is very wide for isolated power systems such as those in the NT. The requirement in the West Australian SWIS is a maximum dead band of +/- 0.025 Hz.
- The droop must be settable in the range 1% to 6%. While a 1% droop is quite aggressive for thermal generation it could be achieved by inverter connected systems.

PWC has advised that while the dead band and droop range is quite wide, to meet the performance standards specified in NTC clause 3.3.5.15, generators will need to select a narrow dead band a low droop setting. GHD accepts this view and therefore does not proposed any revision to the wording specifying the droop setting and dead band.

The NTC GPS provisions don't require the actual provision of any frequency response, but rather just demonstration of a capability to provide a response consistent with the performance standard. While this is consistent with the current provisions in the NER NT it does not align with the approach in other jurisdictions. It is inconsistent with AEMO expressed desire to re-introduce mandatory frequency response in the NEM[4]. The SWIS generator performance guidelines published by Western Power and AEMO propose 4% droop and +/-0.025Hz dead band be met at all times subject to energy source limitations. Isolated power systems such as those in the NT would benefit from the adoption of the approach proposed in the SWIS Generator Performance Guidelines by enhancing frequency control for no additional investment in generating plant.

Requiring frequency control capability to be available at all times, subject to energy source limitations is unlikely to add any significant cost to generation developments. Adopting this change would require frequency controls to be commissioned and left in service so that all generators provide frequency response (subject to energy source limitations) following contingencies. Contingencies are rare events hence there is minimal lost revenue from the actual provision of frequency response.

PWC has advised that they would expect all generators to keep their frequency control systems active at all times. PWC noted that provisions in the SCTC achieve this by requiring generators to maintain a normal mode of operation with active droop control (clause 4.2(b)) while the dispatch requirements in the NTC

[4] Details of the AEMO request can be found on the AEMC website, https://www.aemc.gov.au/rule-changes/mandatory-primary-frequency-response

(clause 9.1.1(e)) specify that a generator must not change its frequency response mode without first gaining permission from the Network Operator. GHD agrees that these provisions allow PWC to ensure that generators maintain an active frequency response capability at all times and therefore revisions to the proposed drafting of the GPS for frequency control are not required to achieve this.

The recommended GPS framework and the referenced provisions in the NTC and SCTC mean that all generators (that are required to have a GPS) must provide capability to deliver frequency response consistent with the GPS specified in NTC clauses 3.3.5.11 and 3.3.5.15. Furthermore all generators must ensure that a frequency response in accordance with their GPS is available at all times, subject to energy source availability. These requirements apply to all generators not just Territory Generation, which is the current provider of frequency control ancillary services.

The current drafting of sub-clause (b) may be interpreted as requiring the generator to be able to increase output in response to a reduction in frequency. Renewable generators will not be able to achieve this capability under most conditions as their output is dependent on energy source availability. GHD recommends this requirement be clarified as being subject to energy source availability.

PWC has proposed amending SCTC clause 4.3(a) by adding sub-clause (7) to clarify that scheduling any ancillary services from Generators other than Territory Generation should not result in a reduced dispatch level. It would be inconsistent with this clause for PWC to constrain off renewable generators to increase the frequency response capability they deliver.

GHD recommends implementing the revised wording in section 3.16.3. This wording reflects a performance standard that should be able to be achieved without imposing significant additional cost on generators. Delivering the performance consistent with the standard will assist in maintaining control of frequency and therefore represents an appropriate balance between generation costs and power system security.

3.16.3 Recommended Wording

Clause 3.3.5.11

3.3.5.11 Frequency Control

(a) For the purpose of this clause 3.3.5.11:

Droop means, in relation to frequency response mode, the percentage change in power system frequency as measured at the connection point, divided by the percentage change in power transfer of the generating system expressed as a percentage of the maximum operating level of the generating system. Droop must be measured at frequencies that are outside the deadband and within the limits of power transfer.

maximum operating level means in relation to:

(1) a *generating unit*, the maximum sent out *generation* consistent with its *nameplate rating* to which it may be dispatched*;* and
(2) a *generating system*, the combined maximum sent out *generation* to which its in-service *generating units* may be dispatched.

minimum operating level means in relation to:

(1) a *generating unit*, its minimum sent out *generation* for continuous stable operation;
(2) a *generating system*, the combined minimum sent out *generation* of its in-service *generating units.*

(b) The automatic access standard is:

(1) subject to energy source availability a *generating system's* power transfer to the power system must not:

(i) increase in response to a rise in the frequency of the power system as measured at the connection point; or
(ii) decrease in response to a fall in the frequency of the power system as measured at the connection point; and

(2) subject to energy source availability a *generating system* must be capable of operating in frequency response mode such that it automatically provides a proportional:

(i) decrease in power transfer to the power system in response to a rise in the frequency of the power system as measured at the connection point; and

(ii) increase in power transfer to the power system in response to a fall in the frequency of the power system as measured at the connection point,

sufficiently rapidly and sustained for a sufficient period for the *Generator* to be in a position to offer measurable amounts of all ancillary services for the provision of power system frequency control.

(c) Each control system used to satisfy this clause 3.3.5.11 must be adequately damped.

(d) The amount of a relevant market ancillary service for which the plant may be registered must not exceed the amount that would be consistent with the performance standard registered in respect of this requirement.

(e) For the purposes of subparagraph (b)(2):

(1) the change in power transfer to the power system must occur with no delay beyond that required for stable operation, or inherent in the plant controls, once the frequency of the power system as measured at the connection point leaves a deadband around 50 Hz;

(2) a generating system must be capable of setting the deadband and droop within the following ranges:

(i) the deadband referred to in subparagraph (1) must be set within the range of 0 to ± 1.0 Hz. Different deadband settings may be applied for a rise or fall in the frequency of the power system as measured at the connection point; and

(ii) the droop must be settable within the range of 1% to 6%, or such other settings as agreed with the *Network Operator* and *Power System Controller*;

(3) nothing in subparagraph (b)(2) is taken to require a *generating system* to operate below its minimum operating level in response to a rise in the frequency of the power system as measured at the connection point, or above its maximum operating level in response to a fall in the frequency of the power system as measured at the connection point; and

(4) the performance standards must record:

(i) agreed values for maximum operating level and minimum operating level, and where relevant the method of determining the values, and the values for a generating system must take into account its in-service generating units; and

(ii) for the purpose of subparagraph (b)(2), the market ancillary services, including the performance parameters and requirements that apply to each such market ancillary service.

3.17 NTC Clause 3.3.5.12 – Impact on Network Capability

3.17.1 Wording proposed by PWC

(a) The automatic access standard is a *generating system* must have plant capabilities and control systems that are sufficient so that when connected it does not reduce any intra-regional power transfer capability below the level that would apply if the *generating system* were not connected.

3.17.2 Observations and Issues Identified

The proposed automatic standard aligns with the automatic access standards in the NER NT.

The NER NT drafting includes guidance on specific matters to consider when negotiating a standard lower than automatic. This information is not included in the proposed wording for the NTC clause. Parties wishing to negotiate a standard lower than the automatic may benefit from referring to this guidance available in the NER NT.

The minimum standard in the NER NT allows for a generation connection to proceed even if it reduces transfer limits as long as the reduced limit does not impede the ability to supply customer load. There may be circumstances where such a relaxation of the automatic access standard is appropriate in the NT power systems.

The NER NT requires that the performance standard include details of any control systems installed to achieve the access standard. It is recommended this provision be added to the NTC drafting:

> “A negotiated access standard under this clause S5.2.5.12 must detail the plant capabilities, control systems and operational arrangements that will be maintained by the Generator, notwithstanding that

change to the power system, but not changes to the generating system, may reduce the efficacy of the plant capabilities, control systems and operational arrangements over time."

The NER NT also provides for the NSP to negotiate commercial terms for the generator to install controls that would enhance transfer limits. There is no similar provision in the NTC drafting, however NTC Clauses 13.8 and 13.9 require non-network options be considered as alternatives to network investments, which is arguably sufficient. For this reason GHD has not recommended any wording changes to address this matter.

In most instances achieving the level of performance specified in the wording proposed by PWC should not add significant cost to generators. GHD is satisfied that the access standard proposed by PWC with the recommended revision is appropriate as it provides an appropriate balance between costs imposed on generators in meeting the standards and the system security benefit delivered. GHD therefore recommends the wording in section 3.17.3 be adopted.

3.17.3 Recommended Wording

Clause 3.3.5.12

(a) The automatic access standard is a *generating system* must have plant capabilities and control systems that are sufficient so that when connected it does not reduce any intra-regional power transfer capability below the level that would apply if the *generating system* were not connected.

A *negotiated access standard* under this clause 3.3.5.12 must detail the *plant* capabilities, *control systems* and operational arrangements that will be maintained by the *Generator*, notwithstanding that change to the *power system*, but not changes to the *generating system*, may reduce the efficacy of the *plant* capabilities, *control systems* and operational arrangements over time.

3.18 NTC Clause 3.3.5.13 – Voltage and Reactive Power Control

3.18.1 Wording proposed by PWC

(a) The voltage and reactive power control automatic access standard is:

(1) The *excitation control system* of a *synchronous generating unit* shall be capable of:

(i) limiting *generating unit* operation at all *load* levels to within *generating unit* capabilities for continuous operation;

(ii) controlling the *generating unit* output to maintain the short-time average *generating unit* output voltage at highest rated level (which shall be at least 5% above the nominal output voltage and is usually 10% above the nominal output voltage);

(iii) maintaining adequate *generating unit* stability under all operating conditions including providing power system stabilising action if fitted with a power system stabiliser;

(iv) in the case of a rotating synchronous generator, the five second ceiling excitation voltage shall be at least twice the excitation voltage required to achieve maximum continuous rating at nominal voltage; and

(v) providing reactive current compensation settable for boost or droop unless otherwise agreed by the *Network Operator*.

(2) The excitation control system of a *generating unit* shall be capable of:

(i) New synchronous *generating units* shall be fitted with fast acting excitation control systems. AC exciter, rotating rectifier or static excitation systems shall be provided for any new *generating units* with a rating greater than 10 MW or for new smaller *generating units* within a power station totalling in excess of 10 MW. Excitation control systems shall provide voltage regulation to within 0.5% of the selected set point value.

(ii) New non-synchronous *generating units* must be fitted with fast acting voltage and / or reactive power control systems, which must utilise modern technology and be approved by the *Network Operator*. Control systems must provide regulation to within 0.5% of the selected set point value.

(iii) Unless agreed by the *Network Operator*, new synchronous *generating units* shall incorporate power system stabiliser circuits that modulate *generating unit* field voltage in response to changes in power output and/or shaft speed and/or any other equivalent input signal approved by the *Network Operator*. The stabilising circuits shall be responsive and adjustable over a frequency range that shall include frequencies from 0.1 Hz to 2.5 Hz.

(iv) The *Network Operator* may require power system stabiliser circuits on synchronous *generating units* with ratings less than or equal to 10 MW or smaller synchronous *generating units* within a power station with a total active power output capability less than or equal to 10 MW (if power system simulations indicate a need for such a requirement). Before commissioning of any power system stabiliser, the *Generator* must propose preliminary settings for the power system stabiliser, which must be approved by the *Network Operator*.

(v) Power system stabilisers may also be required for non-synchronous *generating units*. The performance characteristics of these *generating units* with respect to power system stability must be similar to those required for synchronous *generating units*. The requirement for a power system stabiliser and its structure and settings will be determined by the *Network Operator* from power system simulations.

(vi) Before commissioning of any power system stabiliser, its preliminary settings shall be agreed by the *Network Operator*. The User shall propose these preliminary settings that should be derived from system simulation studies and the study results reviewed by the *Network Operator*.

(vii) The performance characteristics set out in Figure 7 are required for AC exciter, rotating rectifier and static excitation systems.

Figure 7 – *Synchronous Generator* excitation system performance requirements

Performance Item	Units	Static Excitation	A.C. Exciter or Rotating Rectifier	Notes
Sensitivity: A sustained 0.5% error between the *voltage* reference and the sensed *voltage* will produce an excitation *change* of not less than 1.0 per unit.	Open loop gain (ratio)	200 minimum	200 minimum	1
Field *voltage* rise *time*: *Time* for field *voltage* to rise from rated *voltage* to excitation ceiling *voltage* following the application of a short duration impulse to the *voltage* reference.	second	0.05 maximum	0.5 maximum	2
Settling *time* with the *Generator synchronised* following a disturbance equivalent to a 5% step *change* in the sensed *Generator* terminal *voltage*.	second	2.5 maximum	5 maximum	3
Settling *time* with the *Generator unsynchronised* following a disturbance equivalent to a 5% step *change* in the sensed *Generator* terminal *voltage*. Shall be met at all operating points within the *Generator* capability.	second	1.5 maximum	2.5 maximum	3
Settling *time* following any disturbance that causes an excitation limiter to operate.	second	5 maximum	5 maximum	3

Notes:

1. One per unit is that field *voltage* required to produce nominal *voltage* on the air gap line of the *Generator* open circuit characteristic (Refer IEEE Standard 115-1983 – Test Procedures for Synchronous Machines).
2. Rated field *voltage* is that *voltage* required to give nominal *Generator* terminal *voltage* when the *Generator* is operating at its maximum continuous rating. Rise

time is defined as the *time* taken for the field voltage to rise from 10% to 90% of the increment value. 3. Settling time is defined as the time taken for the Generator terminal voltage to settle and stay within an error band of ±10% of its increment value.

(viii) The performance characteristics required for the voltage or reactive power control systems of all non-synchronous *generating units* are specified in Figure 8.

Figure 8 – *Non-synchronous Generator voltage* or *reactive power* control *system* performance requirements

Performance Item	Units	Limiting Value	Notes
Sensitivity: A sustained 0.5% error between the reference *voltage* and the sensed *voltage* must produce an output change of not less than 100% of the *reactive power generation* capability of the generating unit, measured at the point of control.	Open loop gain (ratio)	200 minimum	1
Rise time: Time for the controlled parameter (*voltage* or *reactive power* output) to rise from the initial value to 90% of the change between the initial value and the final value following the application of a 5% step change to the *control system* reference.	second	1.5 maximum	2
Small disturbance settling time Settling time of the controlled parameter with the *generating unit* connected to the *transmission or distribution network* following a step change in the *control system* reference that is not large enough to cause saturation of the controlled output parameter. Must be met at all operating points within the *generating unit's* capability.	second	2.5 maximum	3
Large disturbance settling time Settling time of the controlled parameter following a large disturbance, including a *transmission or distribution network* fault, which would cause the maximum value of the controlled output parameter to be just exceeded.	second	5 maximum	3
Notes: 1. A control system with both proportional and integral actions must be capable of achieving a minimum equivalent gain of 200. 2. The controlled parameter and the point where the parameter is to be measured must be agreed and included in the relevant *connection agreement*.			

3. Settling time is defined as the time taken for the controlled parameter to settle and stay within an error band of ±10% of its increment value.

(ix) The *Network Operator* shall approve the structure and parameter settings of all components of the excitation control system, including the voltage regulator, power system stabiliser, power amplifiers and all excitation limiters.

(x) The structure and settings of the excitation control system shall not be changed, corrected or adjusted in any manner without prior written notification to the *Network Operator*. The *Network Operator* may require *generating unit* tests to demonstrate compliance with the requirements of Figure 7 or Figure 8. The *Network Operator* may witness such tests.

(xi) Settings may require alteration from time to time as advised by the *Network Operator or Power System Controller*. The cost of altering the settings and verifying subsequent performance shall be borne by the User, provided alterations are not made more than once in each 18 months for each *generating unit*. If more frequent changes are requested the person making that request shall pay all costs on that occasion.

(xii) Excitation limiters shall be provided for under excitation and over excitation and may be provided for voltage to frequency ratio. The *generating unit* shall be capable of stable operation for indefinite periods while under the control of any excitation limiter. Excitation limiters shall not detract from the performance of any stabilising circuits and shall have settings applied which are co-ordinated with all protection systems.

3.18.2 Observations and Issues Identified

No specific guidance is provided for negotiation of standard below automatic. Such guidance is offered in NER NT. Parties wishing to negotiate a standard lower than the automatic may benefit from referring to this guidance available in the NER NT.

Various terms are either poorly defined or misused in the proposed drafting creating potential ambiguity:

- rotating rectifier is used but not defined;
- the definition for static excitation system in the glossary is not consistent with the definition in the NER NT as it does not differentiate between static systems and rotating rectifiers.

Clause 3.3.5.13(a)(2) refers to excitation control systems as a collective term applicable to all forms of generation. This is not appropriate as inverter connected generating systems have no excitation system.

The NER NT S5.2.5.13(b)(1) requires that all generating systems provide plant capabilities and control systems sufficient to ensure stable operation from the perspective of oscillatory stability. NTC Clause 3.3.5.13(a)(1)(iii) attempts to impose similar but not identical provisions on synchronous generators. There are no provisions in the proposed GPS revisions to the NTC that impose these obligations on non-synchronous generation. It is recommended that the proposed clause 3.3.5.13(a)(1)(iii) be deleted and the wording from the NER NT be included to address this issue. Oscillatory behaviour at solar farms in

Western Victoria is currently creating system security concerns in the NEM, this underlines the importance of having all large generators designed to avoid introducing oscillatory stability issues.

The NER NT S5.2.5.13(b)(2) requires that all control systems incorporate adequate disturbance monitoring and testing facilities. Continuous high speed monitoring is the most cost effective means of assessing ongoing generator compliance with performance standards and the technology is not an expensive addition to new generating system. It is therefore recommended that a similar requirement be included in the NTC.

The NER NT S5.2.5.13(b)(2A) requires all generating systems have the capability to control voltage, reactive power or power factor and the ability to switch between control modes. This requirement is missing from the proposed revisions to the NTC. The proposed revisions require a single control mode agreed with the Network Operator. Experience elsewhere suggests this approach is likely to be sufficient and no change from the proposed drafting is recommended.

Much of the wording of this clause is significantly different to the NER NT, however many of the technical requirements expressed are similar and consistent with current NT regulations and therefore no change is recommended for those requirements as they reflect current practice for connection of generators to NT power systems.

The required range for the voltage and reactive power set point values are not well defined. There are some technical requirements that differ and revisions to the proposed drafting should be considered to address these:

- NER NT voltage set point range – 95% to 105% for all generating systems, whereas NTC revisions only specify an upper limit for synchronous generating systems and no limits for non-synchronous systems;
- NER NT specifies performance requirements for limiters in S5.2.5.13(h). Those requirements are missing from the NTC and should be included.

GHD recommends the wording in section 3.18.3 be adopted. Achieving the level of performance specified in the recommended wording should not add significant cost to generators compare to the faced historically to connect to the NT power systems. GHD is therefore satisfied that the access standard recommended is appropriate as it provides an appropriate balance between costs imposed on generators in meeting the standards and the system security benefit delivered.

3.18.3 Recommended Wording

Clause 3.3.5.13

(a) For the purpose of this clause 3.3.5.13:

> **static excitation system** means in relation to a *synchronous generating unit*, an *excitation control system* that does not use rotating machinery to produce the field current.

(b) The voltage and reactive power control automatic access standard is:

(1) The *excitation control system* of a *synchronous generating unit* shall be capable of:

(i) limiting *generating unit* operation at all *load* levels to within *generating unit* capabilities for continuous operation;

(ii) controlling the *generating unit* output to maintain the short-time average *generating unit* output voltage at highest rated level (which shall be from a maximum of 5% below the nominal output voltage to at least 5% above the nominal output voltage and is usually 10% above the nominal output voltage);

(iii) ensuring that plant capabilities and control systems are sufficient such that:

a. power system oscillations, for the frequencies of oscillation of the generating unit against any other generating unit, are adequately damped;

b. operation of the generating system does not degrade the damping of any critical mode of oscillation of the power system; and

c. operation of the generating system does not cause instability (including hunting of tap-changing transformer control systems) that would adversely impact other Registered Participants.

(iv) in the case of a rotating synchronous generator, the five second ceiling excitation voltage shall be at least twice the excitation voltage required to achieve maximum continuous rating at nominal voltage; and

(v) providing reactive current compensation settable for boost or droop unless otherwise agreed by the *Network Operator*.

(2) The excitation control system of a synchronous *generating unit* shall be capable of:

(i) New synchronous *generating units* shall be fitted with fast acting excitation control systems. AC exciter, rotating rectifier or static excitation systems shall be provided for any new *generating units* with a rating greater than 10 MW or for new smaller *generating units* within a power station totalling in excess of 10 MW. Excitation control systems shall provide voltage regulation to within 0.5% of the selected set point value.

(ii) New non-synchronous *generating units* must be fitted with fast acting voltage and / or reactive power control systems, which must utilise modern technology and be approved by the *Network Operator*. Control systems must provide regulation to within 0.5% of the selected set point value.

(iii) Unless agreed by the *Network Operator*, new synchronous *generating units* shall incorporate power system stabiliser circuits that modulate *generating unit* field voltage in response to changes in power output and/or shaft speed and/or any other equivalent input signal approved by the *Network Operator*. The stabilising circuits shall be responsive and adjustable over a frequency range that shall include frequencies from 0.1 Hz to 2.5 Hz.

(iv) The *Network Operator* may require power system stabiliser circuits on synchronous *generating units* with ratings less than or equal to 10 MW or smaller synchronous *generating units* within a power station with a total active power output capability less than or equal to 10 MW (if power system simulations indicate a need for such a requirement). Before commissioning of any power system stabiliser, the *Generator* must propose preliminary settings for the power system stabiliser, which must be approved by the *Network Operator*.

(v) Power system stabilisers may also be required for non-synchronous *generating units*. The performance characteristics of these *generating units* with respect to power system stability must be similar to those required for synchronous *generating units*. The requirement for a power system stabiliser and its structure and settings will be determined by the *Network Operator* from power system simulations.

(vi) Before commissioning of any power system stabiliser, its preliminary settings shall be agreed by the *Network Operator*. The User shall propose these preliminary settings that should be derived from system simulation studies and the study results reviewed by the *Network Operator*.

(vii) The performance characteristics set out in Figure 7 are required for AC exciter, rotating rectifier and static excitation systems.

Figure 7 – *Synchronous Generator* excitation system performance requirements

Performance Item	Units	Static Excitation	A.C. Exciter or Rotating Rectifier	Notes
Sensitivity: A sustained 0.5% error between the *voltage* reference and the sensed *voltage* will produce an excitation *change* of not less than 1.0 per unit.	Open loop gain (ratio)	200 minimum	200 minimum	1
Field *voltage* rise *time*: *Time* for field *voltage* to rise from rated *voltage* to excitation ceiling *voltage* following the application of a short duration impulse to the *voltage* reference.	second	0.05 maximum	0.5 maximum	2
Settling *time* with the *Generator synchronised* following a disturbance equivalent to a 5% step *change* in the sensed *Generator* terminal *voltage*.	second	2.5 maximum	5 maximum	3
Settling *time* with the *Generator unsynchronised* following a disturbance equivalent to a 5% step *change* in the sensed *Generator* terminal *voltage*. Shall be met at all operating points within the *Generator* capability.	second	1.5 maximum	2.5 maximum	3
Settling *time* following any disturbance that causes an excitation limiter to operate.	second	5 maximum	5 maximum	3

Notes:

1. One per unit is that field *voltage* required to produce nominal *voltage* on the air gap line of the *Generator* open circuit characteristic (Refer IEEE Standard 115-1983 – Test Procedures for Synchronous Machines).
2. Rated field *voltage* is that *voltage* required to give nominal *Generator* terminal *voltage* when the *Generator* is operating at its maximum continuous rating. Rise *time* is defined as the *time* taken for the field voltage to rise from 10% to 90% of the increment value.
3. Settling time is defined as the time taken for the Generator terminal voltage to settle and stay within an error band of ±10% of its increment value.

(viii) The performance characteristics required for the voltage or reactive power control systems of all non-synchronous *generating units* are specified in Figure 8.

Figure 8 – *Non-synchronous Generator voltage* or *reactive power* control *system* performance requirements

Performance Item	Units	Limiting Value	Notes
Sensitivity: A sustained 0.5% error between the reference *voltage* and the sensed *voltage* must produce an output change of not less than 100% of the *reactive power generation* capability of the generating unit*,* measured at the point of control.	Open loop gain (ratio)	200 minimum	1
Rise time: Time for the controlled parameter (*voltage* or *reactive power* output) to rise from the initial value to 90% of the change between the initial value and the final value following the application of a 5% step change to the *control system* reference.	second	1.5 maximum	2
Small disturbance settling time Settling time of the controlled parameter with the *generating unit* connected to the *transmission or distribution network* following a step change in the *control system* reference that is not large enough to cause saturation of the controlled output parameter. Must be met at all operating points within the *generating unit's* capability.	second	2.5 maximum	3
Large disturbance settling time Settling time of the controlled parameter following a large disturbance, including a *transmission or distribution network* fault, which would cause the maximum value of the controlled output parameter to be just exceeded.	second	5 maximum	3

Notes:

1. A control system with both proportional and integral actions must be capable of achieving a minimum equivalent gain of 200.
2. The controlled parameter and the point where the parameter is to be measured must be agreed and included in the relevant *connection agreement*.
3. Settling time is defined as the time taken for the controlled parameter to settle and stay within an error band of ±10% of its increment value.

(ix) The *Network Operator* shall approve the structure and parameter settings of all components of the excitation control system, including the voltage regulator, power system stabiliser, power amplifiers and all excitation limiters.

(x) The structure and settings of the excitation control system shall not be changed, corrected or adjusted in any manner without prior written notification to the *Network Operator*. The *Network Operator* may require *generating unit* tests to demonstrate compliance with the requirements of Figure 7 or Figure 8. The *Network Operator* may witness such tests.

(xi) Settings may require alteration from time to time as advised by the *Network Operator or Power System Controller*. The cost of altering the settings and verifying subsequent performance shall be borne by the User, provided alterations are not made more than once in each 18 months for each *generating unit*. If more frequent changes are requested the person making that request shall pay all costs on that occasion.

(xii) Excitation limiters shall be provided for under excitation and over excitation and may be provided for voltage to frequency ratio. The *generating unit* shall be capable of stable operation for indefinite periods while under the control of any excitation limiter. Excitation limiters shall not detract from the performance of any power system stabiliser or power oscillation damping capability and shall have settings applied which are co-ordinated with all protection systems.

(3) a control system must have:

(i) for the purposes of disturbance monitoring and testing, permanently installed and operational, monitoring and recording facilities for key variables including each input and output; and

(ii) facilities for testing the control system sufficient to establish its dynamic operational characteristics.

The following definition needs to be added to the glossary of terms in Attachment 1 to the NTC:

rotating rectifier

A type of brushless excitation system for a *synchronous generating unit.*

3.19 NTC Clause 3.3.5.14 – Active Power Control

3.19.1 Wording proposed by PWC

(a) The active power control automatic access standard is a *generating system* must have an active power control system capable of:

(1) For a scheduled generating unit or scheduled generating system:

(i) Maintaining and changing its active power output in accordance with its dispatch instructions; and

(ii) Receiving and automatically responding to AGC signals as updated (nominal update rate of once per four seconds)

(b) Each control system used to satisfy the requirements of paragraph (a) must be adequately damped.

(c) Settings may require alteration from time to time as advised by the *Network Operator or Power System Controller*. The cost of altering the settings and verifying subsequent performance shall be borne by the User, provided alterations are not made more than once in each 18 months for each *generating unit*. If more frequent changes are requested the person making that request shall pay all costs on that occasion.

(d) A *generating system* must be capable of ramping its active power output linearly at a rate not slower than 5% of nameplate rating per minute.

3.19.2 Observations and Issues Identified

No specific guidance is provided for negotiation of standard below automatic. Guidance for negotiation is offered in NER NT. Parties wishing to negotiate a standard lower than the automatic may benefit from referring to this guidance available in the NER NT.

The wording for the NTC clause proposed by PWC specifies a minimum ramping rate (at least 5% of nameplate per minute). The NER NT only requires that ramping be done linearly from one dispatch target to another. The proposed wording for the NTC clause is acceptable, the linear ramping requirement in the NER NT reflects characteristics of the NEM dispatch system and need not be replicated in NT power systems.

NER NT specifies differing requirements for scheduled, semi-scheduled and non-scheduled generators and the automatic standard in the NER NT specifies that requirements are subject to energy source availability for generating units that are not scheduled. The lack of recognition of energy source availability in the NTC creates ambiguity regarding whether the required capability is to be delivered under all conditions.

It is recommended that the requirements be qualified to be subject to energy source availability.

Achieving the level of performance specified in the wording proposed by PWC should not add significant cost to generators. GHD is satisfied that the access standard proposed by PWC with the recommended revision is appropriate as it provides an appropriate balance between costs imposed on generators in meeting the standards and the system security benefit delivered. GHD therefore recommends the wording in section 3.19.3 be adopted.

3.19.3 Recommended Wording

(a) Subject to energy source availability, the active power control automatic access standard is a *generating system* must have an active power control system capable of:

(i) Maintaining and changing its active power output in accordance with its dispatch instructions; and

(ii) Receiving and automatically responding to AGC signals as updated (nominal update rate of once per four seconds)

(b) Each control system used to satisfy the requirements of paragraph (a) must be adequately damped.

(c) Settings may require alteration from time to time as advised by the *Network Operator or Power System Controller*. The cost of altering the settings and verifying subsequent performance shall be borne by the User, provided alterations are not made more than once in each 18 months for each *generating unit*. If more frequent changes are requested the person making that request shall pay all costs on that occasion.

(d) A *generating system* must be capable of ramping its active power output linearly at a rate not slower than 5% of nameplate rating per minute.

3.20 NTC Clause 3.3.5.15 – Inertia and Contingency FCAS

3.20.1 Wording proposed by PWC

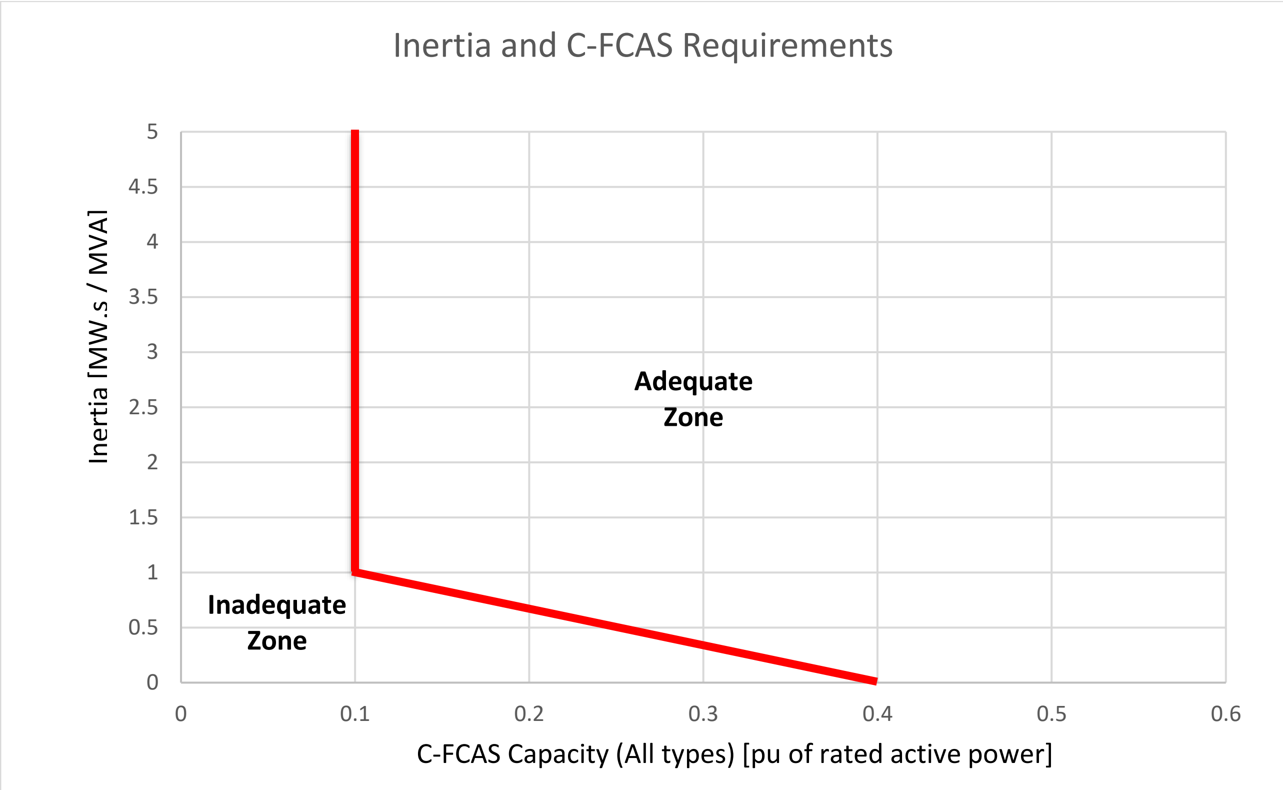
(a) The *inertia* and *contingency FCAS* automatic access standard is:

(1) A *generating system* must have an adequate *inertia* and *contingency FCAS* capability as defined by the characteristic below. The capability must be able to be dispatched up to a point within the adequate zone as shown, and can be achieved by any combination of partially loaded *generating unit(s)*, and/or additional plant (e.g. synchronous condensers, energy storage system, etc..), to achieve the required capability.

(2) *Inertia* offered or provided from non-synchronous (emulated) sources needs to be assessed and accepted by the *Power System Controller* and *Network Operator*.

(3) The *inertia* and *FCAS* capabilities will be accredited by the *Power System Controller* using the specifications and evaluation framework outlined in the System Secure Guidelines.

Figure 9 – Inertia vs C-FCAS Trade Off Requirements for New Generators



3.20.2 Observations and Issues Identified

The changes to the NTC introduce a requirement for generators to be capable of providing a combination of Inertia and C-FCAS capability. Neither term is defined sufficiently in the NTC for generators to be able to assess their ability to meet the automatic access standard.

The proposed drafting requires the specifications and evaluation framework in the system secure guidelines (SSG) to be used by the Power System Controller to provide accreditation of a generating system's C-FCAS and Inertia capability. While the Utilities Commission does not have a role in reviewing or approving the Secure System Guidelines, the content of the guidelines will dictate whether this performance standard as drafted is acceptable.

The version of SSG provided by PWC lacks sufficient detail to allow a generation developer to assess the level of C-FCAS their plant would be assessed as providing. This gap should be addressed by PWC in subsequent drafts if the SSG. The lack of detail in the SSG will impede a generator's ability to understand the investment required to achieve a C-FCAS performance level. GHD would recommend that the SSG specify precisely how the C-FCAS capability provided by a generator will be assessed. For clarity we recommend providing worked examples illustrating the calculation for a solar farm providing no inertia and a synchronous generator providing inertia.

The PWC submission suggests that generators must be capable of providing C-FCAS in the raise and lower direction subject to energy supply limitations, however the proposed drafting does not provide certainty regarding the requirement. It is recommended that sub-clause (a)(1) be altered to:

> "A generating system must have an adequate inertia and contingency FCAS capability as defined by the characteristic below. Subject to energy source availability, the generating system must be able operate at a real power output that will deliver inertia and contingency FCAS capability within the adequate zone as shown. The required capability can be achieved by any combination of partially loaded generating unit(s), and/or additional plant (e.g. synchronous condensers, energy storage system, etc.)."

The proposed amendment provides clarity for generators that there is no expectation that they provide contingency FCAS capability if there is insufficient energy source availability (i.e. insufficient sunlight to achieve an increase in output). However they do not provide any clarity for the generators regarding the conditions under which PWC may choose to constrain their output to provide increase raise contingency FCAS capability. As noted in section 3.16.2 this matter has been raised with PWC who confirmed that there is no intention to constrain renewable generation if sufficient contingency raise FCAS is available from other generation sources. Revisions proposed to the SCTC clause 4.3(a) clarify this position. PWC expects that under most conditions contingency raise capability will be provided by head room available on thermal generators. During periods of high solar generation thermal generators will be operating a reduced output which should provide sufficient raise capability.

PWC expects that the Power System Controller and Network Operator will not constrain the real power output of a generating system to increase the available contingency FCAS response unless there is an ancillary service agreement in place with the generator that provides for such action.

GHD's review of the relevant provisions of the SCTC and the NTC defining dispatch requirements, the revisions proposed to clause 4.3(a) of the SCTC and recommended revisions to the NTC to introduce GPS, has confirmed that the proposed regulations as a whole supports the advice provided by PWC and it is therefore unlikely that renewable generator will be constrained off to provide additional contingency frequency response capability.

Renewable generators will be expected to provide contingency lower FCAS under most conditions. This should not impose a significant cost on generators as in the absence of any contingency there is no constraint on the output of the generator. Contingencies are rare events hence there is minimal lost revenue from the actual provision of frequency response following a load contingency.

GHD recommends the wording in section 3.20.3 be adopted. The recommended wording provides greater clarity regarding the C-FCAS requirement which should be able to be met by generators without significant additional capital cost and without significant levels of constrained operation. GHD is satisfied that the access standard proposed by PWC with the recommended revision is appropriate as it provides an appropriate balance between costs imposed on generators in meeting the standards and the system security benefit delivered. GHD recommends that revisions to the SSG are made to better clarify how the C-FCAS capability will be assessed as this will assist generators in designing the control systems they implement to respond to changes in system frequency.

The continual provision of lower contingency FCAS capability by renewable generators means that it is important that adjustments are made to the capacity forecasting GPS to make sure that departing from a forecast dispatch target to correct frequency is not penalised. Wording changes for this issue are presented in section 3.22 of this report.

3.20.3 Recommended Wording

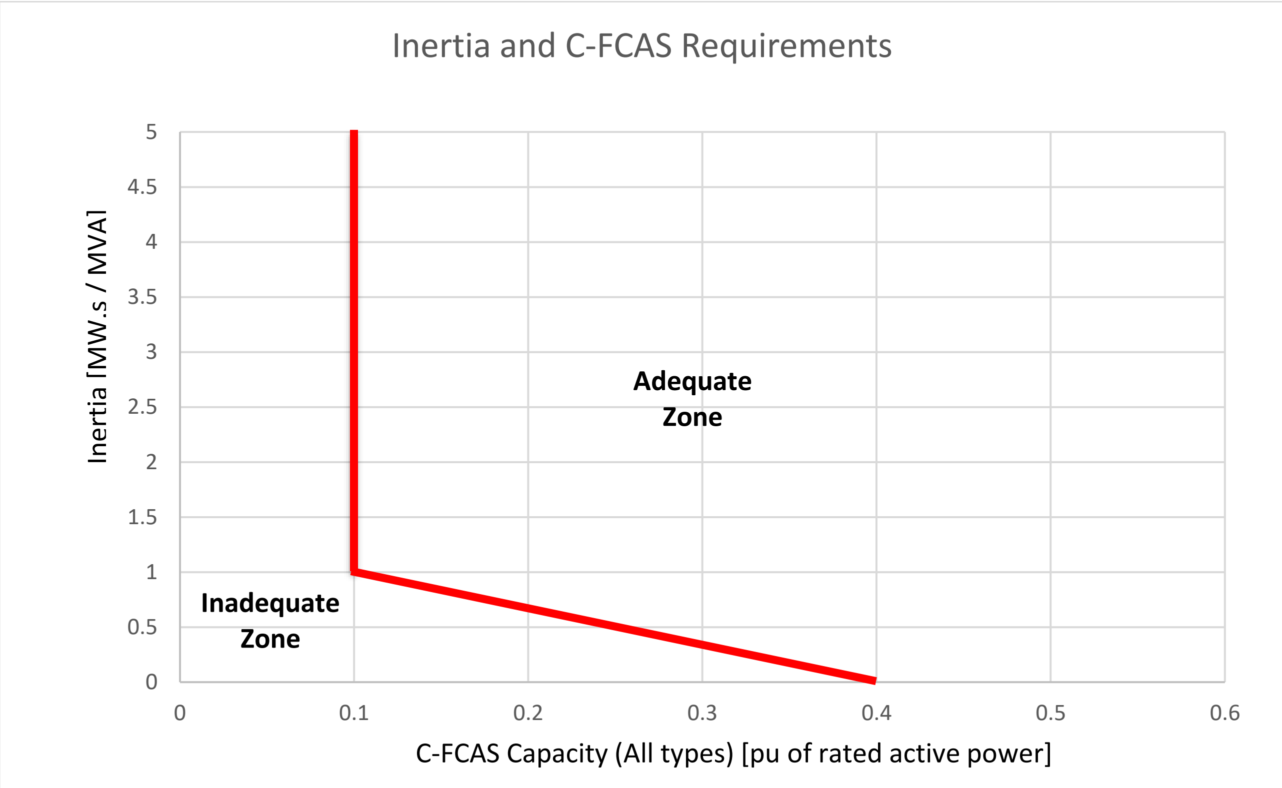
(a) The *inertia* and *contingency FCAS* automatic access standard is:

(1) A *generating system* must have an adequate *inertia* and *contingency FCAS* capability as defined by the characteristic below. Subject to energy source availability, the *generating system* must be able to operate at a real power output that will deliver *inertia* and *contingency FCAS* capability within the adequate zone as shown. The required capability can be achieved by any combination of partially loaded *generating unit(s)*, and/or additional plant (e.g. *synchronous condensers*, energy storage system, etc.), to achieve the required capability.

(2) *Inertia* offered or provided from non-synchronous (emulated) sources needs to be assessed and accepted by the *Power System Controller* and *Network Operator*.

(3) The *inertia* and *FCAS* capabilities will be accredited by the *Power System Controller* using the specifications and evaluation framework outlined in the System Secure Guidelines.

Figure 9 – Inertia vs C-FCAS Trade Off Requirements for New Generators



3.21 NTC Clause 3.3.5.16 – System Strength

3.21.1 Wording proposed by PWC

(a) The system strength automatic access standard is a *generating system* must not cause an adverse impact on system strength as defined in the AEMO System Strength Impact Assessment Guidelines v1.0 July 2018 and following an assessment by the *Network Operator*.

Subject to paragraph (a),

(1) a *Network Operator* must undertake system strength connection works at the cost of the connection applicant if the full assessment undertaken in accordance with the AEMO system strength impact assessment guidelines indicates that the connection applicant's proposed new connection of a generating facility or the *Generator*'s proposed alteration to a generating system will have an adverse system strength impact, or

(2) to the extent that the adverse system strength impact referred to in paragraph (a) is or will be avoided or remedied by a system strength remediation scheme agreed or determined under this clause and implemented by the connection applicant in accordance with its *connection agreement*.

    (i) A connection applicant proposing to install plant as part of a system strength remediation scheme must include a description of the plant, the ratings of the proposed plant (in MVA) and other information (including models) reasonably required by the *Network Operator* and *Power System Controller* to assess the system strength remediation scheme.

3.21.2 Observations and Issues Identified

There is no specific performance standard specified in the NER NT or NER addressing system strength.

The NTC drafting relies on the System Strength Impact Assessment Guidelines that AEMO is required to develop under clause 4.6.6 of the NER. This clause has not been adopted in the NER NT and it is unreasonable to assume that the AEMO guideline has been developed for use in the NT. A similar concern arose when developing system strength provisions for the SWIS. The approach adopted in that instance was for a requirement to be placed on the Network Operator (Western Power) to develop a system strength impact assessment guideline for the SWIS. This approach requires Western Power to review the AEMO guideline and adopt those aspects that are applicable in the SWIS.

GHD recommends the NTC include a provision for PWC to develop and maintain a System Strength Impact Assessment Guideline appropriate for the NT power systems. This requirement could be met by PWC reviewing and leveraging the AEMO guideline as appropriate for NT power systems. The requirement ensures that specific consideration is given to the technical characteristics of the NT power systems and if necessary refinements to the AEMO guideline are implemented in developing an appropriate guideline for application in the NT power systems.

The AEMO assessment guidelines require a two stage assessment, while the preliminary assessment can be made with power system models used for power flow and fault calculations, the detailed assessment requires access to an Electromagnetic Transient model (EMT) of the power system and connected generators. Revisions have been recommended to the model provision requirements in clause 3.3.4 of the NTC to include provision of an EMT model for connecting generators. The inclusion of this requirement aligns with advice provided by PWC that they currently request generators to provide such models. The provision of EMT models by generators should allow PWC to develop and maintain EMT models for the NT power systems allowing the application of the detailed assessment procedure described in the AEMO System Strength Impact Assessment Guidelines.

The wording proposed by PWC refers to various terms that are not defined in the glossary. The definitions in the NER NT should be adopted for the following terms:

- system strength connection works
- adverse system strength impact
- system strength remediation scheme

The proposed revisions to the drafting for this performance standard reflect contemporary requirements implemented in other power systems across Australia. This approach is considered appropriate for the NT power systems. As the assessment of performance against the standard requires the application of the AEMO guideline it is recommended that PWC carefully review the guideline to ensure it is suitable for use in each of the NT power systems. If the guideline needs modification, PWC should produce a revised version of the guideline applicable for the NT and that version should be referred to in the clause 3.3.5.16 of the NTC.

GHD recommends the wording in section 3.21.3 be adopted as it represents an appropriate balance between imposing costs through the generator connection process and maintaining system security.

3.21.3 Recommended Wording

Clause 3.3.5.16

(a) The *Network Operator* must prepare system strength impact assessment guidelines. In preparing the first version of the guidelines, the *Network Operator* must review the AEMO System Strength Impact Assessment Guidelines v1.0 July 2018 and adopt those aspects of that document that are appropriate to apply in the Northern Territory together with any other provisions the *Network Operator* considers appropriate. The *Network Operator* may amend the guidelines at any time, and must review the guidelines when any changes are made to the AEMO guidelines. The *Network Operator* must consult with *Users* before issuing or amending the guidelines.

(b) The system strength *automatic access standard* is a *generating system* must not cause an adverse impact on system strength as defined in the system strength impact assessment guidelines and following an assessment by the *Network Operator*.

Subject to paragraph (a),

(1) a *Network Operator* must undertake system strength connection works at the cost of the connection applicant if the full assessment undertaken in accordance with the system strength impact assessment guidelines indicates that the connection applicant's proposed new connection of a generating facility or the *Generator*'s proposed alteration to a generating system will have an adverse system strength impact, or

(2) to the extent that the adverse system strength impact referred to in paragraph (a) is or will be avoided or remedied by a system strength remediation scheme agreed or determined under this clause and implemented by the connection applicant in accordance with its *connection agreement*.

(i) A connection applicant proposing to install plant as part of a system strength remediation scheme must include a description of the plant, the ratings of the proposed plant (in MVA) and other information (including models) reasonably required by the *Network Operator* and *Power System Controller* to assess the system strength remediation scheme.

The following definitions need to be added to the glossary of terms in attachment 1 to the NTC:

system strength connection works

Investment in a *transmission or distribution system* in order to remedy or avoid an *adverse system strength impact* arising from establishing a *connection* for a *generating system* or *market network service facility* or from any alteration to a *generating system*.

adverse system strength impact

An adverse impact, assessed in accordance with the *system strength impact assessment guidelines*, on the ability under different operating conditions of:

(a) the power system to maintain system stability; or

(b) a generating system or market network service facility forming part of the power system to maintain stable operation including following any credible contingency event or protected event,

so as to maintain the power system in a *secure operating state*.

system strength remediation scheme

A scheme required to be implemented as a condition of a *connection agreement* to remedy or avoid an *adverse system strength impact*.

system strength impact assessment

Power system studies to assess the impact of the *connection* of a new *generating system* or of any proposed alteration to a *generating system* on the ability under different operating conditions of:

(a) the power system to maintain system stability; and

(b) generating systems and market network service facilities forming part of the power system to maintain stable operation including following any credible contingency event or protected event,

so as to maintain the *power system* in a *secure operating state*.

system strength impact assessment guidelines

The guidelines for conducting *system strength impact assessments* developed by the Network Operator under clause 3.3.5.16.

3.22 NTC Clause 3.3.5.17 – Capacity Forecasting

3.22.1 Wording proposed by PWC

(a) In this clause 3.3.5.17, the following terms apply:

(1) ‘t’ is time.

(2) 't=0' refers to the moment when a forecast is updated.

(3) 't=[numeral]' refers to the number of minutes elapsed since t=0.

(4) 'capacity' means the minimum capability of a *generating system* to deliver an active power output at a continuous steady level over the relevant 5 minute interval.

(5) 'firm offer' means the capacity forecast provided at t=0 for the interval commencing t=0 for 5 minutes

(6) 'dispatch capacity' means the capacity instructed to the *Generator* to be injected into the grid.

(7) 'actual capacity' means the minimum instantaneous power injected into the grid for the interval commencing t=0 for 5 minutes.

(b) The capacity forecasting automatic access standard is:

(1) A *Generator* must supply to the *Power System Controller* a forward forecast of the capacity of its *generating system*.

(2) The forecast in 3.3.5.17(b)(1) must:

(i) include a 24 hour ahead forecast for capacity for every 5 minute interval, updated at 5 minute intervals; and

(ii) have an accuracy such that in any rolling 24 hour period at 90% of the non-zero forecasts for the intervals commencing from t=5 to t=30 do not exceed the firm offer for the time for which the forecast was made.

(3) For the 10% of forecast updates that do not meet paragraph (2)(ii) above, the forecast must not exceed the firm offer by a margin greater than:

(i) 5% of the *generating unit's* nameplate rating; or

(ii) 1 MW,

whichever is the lesser.

(4) The actual capacity must be within +/- 0.5% of the dispatch capacity.

Note: When issuing dispatch instructions, the System Controller will respect plant limits such as firm offers and ramp rates of plant.

(c) A *Generator* must provide forecasts to the *Power System Controller* in a format specified by the *Power System Controller*.

(d) The *generating system* owner will be required to report compliance against the above requirements in a format and timeframe determined by the *Power System Controller*.

(e) In the event of non-compliance with the automatic access standard by a *Generator*, the *Power System Controller* may adjust that *Generator's* subsequent forecasts and firm offers accordingly.

3.22.2 Observations and Issues Identified

Clarity of requirements and response to non-compliance

Several stakeholders have raised concerns in their submissions to PWC regarding the introduction of the capacity forecasting accuracy requirements as part of the GPS to NT power systems. The submissions cite a number of concerns including:

- the cost of complying with the automatic access standard proposed threatens the commercial viability of new solar generation projects
- the forecast accuracy requirement prevents the adoption of other more efficient measures such as central batteries shared by a number of generators, and
- the forecast accuracy requirement is difficult to meet for generators developed behind the meter and operating with a zero-export connection agreement.

GHD agrees that the capacity forecasting requirements are unique in the Australian context and that the capacity forecast accuracy requirements and the surrounding compliance process needs further clarification to enable generator developers to assess how best to invest to meet these requirements. Further clarity is required regarding the proposed accuracy requirement, the manner in which PWC will assess whether accuracy requirements are being met and the approach PWC will take in response to any failure to meet the forecast accuracy requirements. We recommend that PWC develop and publish the procedure that will be followed by the Network Operator, if a breach of the performance standard is detected. The published procedure should clarify the process the Network Operator will use and to the Network Operator will consider the difference between the actual performance and the performance requirement specified in the GPS when deciding on the appropriate action to take following detection of a non-compliance.

Providing sufficient information on the accuracy requirements and the compliance process should allow generators to develop the most efficient solution for their projects that appropriately balances the cost of meeting the accuracy requirements and the risk to their operation of a breach of those performance requirements. This information is also crucial to allow a generator to assess whether there is merit in submitting a proposal for a negotiated performance standard and to develop the information necessary to support the adoption of a negotiated performance standard.

Our review identified a number of discrepancies between information provided in the submission prepared by PWC and the proposed wording for clause 3.3.5.17 of the NTC. Through discussion with PWC the following points were clarified:

- There are three accuracy requirements that need to be met
- The first measures the alignment between the actual capacity and the dispatch capacity. Those two quantities must differ by less than +/- 0.5% of the dispatch capacity for every dispatch interval
- The next two assess the alignment between the firm offer and the six forecasts updated each five minutes for the 30 minutes prior to the firm offer being submitted. There are two accuracy thresholds which need to be met:
    - The six forecasts are compared with the firm offer and any non-zero forecast which is lower than the firm offer is counted. The process is repeated for all firm offers across a rolling 24

hour window. To meet the accuracy requirement at least 90% of the non-zero forecasts must be must be less than their respective firm offer.

  - The last accuracy requirement is that any of the forecasts that are higher than the firm offer, must not exceed the firm offer by:
    - 5% of the generating unit's nameplate rating; or
    - 1MW, whichever is the lesser.

The wording for sub-clause (3) needs to be revised to correctly reflect the above accuracy requirements.

The accuracy requirements encourage generators to under bid their capacity in the 5 to 30 minute ahead forecast to reduce the risk that the forecasts ever exceed the firm offer and reduce the risk that the 90% accuracy requirement is breached. The risk with this approach is that additional capacity offered in the firm offer that was not offered in the 30 minute ahead forecast may not be dispatched by system control. This could arise as a result of the scheduling of thermal generators being set based on the 30 minute out forecast and not being able to accommodate increased output from the renewable generator. This is probably a low risk as maximising the dispatch of renewable generation should in most instances lead to a more efficient dispatch result and therefore a better result from the dispatch objective.

Sub-clause (e) allows the Power System Controller to adjust subsequent forecasts and firm offers if a generator is found to be non-compliant with forecasting accuracy requirements. The drafting lacks sufficient precision for a generator to quantify the risk to their revenue of a forecasting breach. PWC has advised that they are preparing an outage management procedure that will provide information on a range of topics including the process PWC will take following the detection of a non-compliance with the forecast accuracy requirement. Providing sufficient information in that document, is important to allow generators the ability to understand the curtailment risk they might face. This will help generation proponents to optimise the investment they make in forecasting systems and energy storage systems to adequately manage the curtailment risk.

The accuracy requirement proposed by PWC could be achieved by generators adopting conservative forecasts of their solar generation capacity. A conservative forecast could be developed by considering the probability of a forecast error given expected weather conditions and applying a discount to the forecast capacity to provide sufficient confidence that the forecast capacity would be achieved at the time of dispatch. While this approach may avoid or reduce the risk of any non-compliance it could result in periods where the generation dispatched from the solar farm is significantly lower than the generation available if the irradiance levels at the time of dispatch was fully utilised. The outcome could arise if:

- the solar capacity forecast available when generation commitment decisions are made by the Network Operator (30 minutes ahead of dispatch)[5] is lower than the firm offer made 5 minutes ahead of dispatch. Increasing the solar dispatch to the firm offer may not be possible if that would require thermal generators to be dispatched below technical minimums. In this scenario actual solar dispatch is less than that reflected in the firm offer indicating underutilised solar generation capacity.
- the firm offer under estimates the actual solar generation that could have been achieved during the dispatch interval.

[5] PWC have indicated that forecasts available in the pre-dispatch time frame (30 minutes ahead of dispatch) are used to decide on the commitment of thermal generation – see page 31 of the PWC submission to the Utilities Commission

Of these the first scenario may be unlikely as the dispatch principles defined in clause 4.3 of the SCTC require the Network Operator to implement economic dispatch. Economic dispatch principles should allow solar generation to be dispatched in preference to thermal generators which have higher variable costs.

Adopting a conservative forecast approach utilising state of the art forecasting systems may be seen by an investor as a prudent strategy as it could delay investment in more expensive battery storage.

Meeting the accuracy requirements while avoiding the risk of under-utilised solar capacity will probably require some level of additional investment in a battery energy storage system (BESS). The cost of this investment will depend on the use case assumed for BESS sizing. Developing the appropriate BESS use case requires a detailed understanding of the expected performance of the installed solar forecasting system, the forecast accuracy requirement and the actions PWC will take in response to any non-compliance with the forecast accuracy requirement.

A risk adverse investor may want to avoid any curtailment risk. That could require a BESS which is sufficient to mitigate a worst case cloud event and have no change between the 35 minute ahead forecast and actual dispatch. That would require a BESS with a maximum discharge capacity of approximately 80% of the solar farm capacity and an energy storage capacity sufficient to store 80% of the maximum energy output from a solar farm for at least 30 minutes. For a 25 MW solar farm this requires a BESS rated at 20MW/10MWh which could cost up to $10 M (input assumptions 2019 ISP).

BESS costs are predicted to fall over the coming years so there is significant economic benefit in delaying investment until the need is proven.

GHD has recommended a number of revisions to the drafting proposed by PWC to clarify the forecast accuracy requirements. We have also recommended an addition to the NTC requiring PWC to produce a procedure that details the process the Network Operator will use to detect any non-compliance with the capacity forecasting performance standard and the process that will be used to determine the action taken in response to any non-compliance with that performance standard.

Balance of system risk verses generation project cost

The proposed accuracy requirements have the potential to impose significant cost on renewable generators. It is therefore necessary to consider whether the accuracy requirements are overstated or represent a level of performance which is appropriate to manage the impact of the variability of renewable generation on other network users. The submissions and consultation documents published by PWC present some analysis to justify the setting selected for capacity forecasting accuracy requirement.

Their analysis appears to have considered 12 months of actual dispatch data for the DKIS on top of which they have overlaid the potential operation of 120 MW of solar generation. PWC applied a forecast accuracy model that varied the percentage of periods for which the forecast capacity was greater than the actual capacity and the maximum amount by which the forecast capacity exceeded the actual capacity. The analysis was used to assess how often the SSG were breached.

The results are shown in Table 2.1 extracted from the PWC submission, show the percentage of daylight periods which would have breached the SSGs. The columns rows in the table differentiate between different aspects of the assumed accuracy of the solar forecast with the columns varying the percentage of periods for which the forecast exceeded the actual capacity and the rows showing the maximum amount by which the forecast capacity exceeded the actual capacity.

Table 2.1: Percentage of Daylight Periods with SSG breach

		Percent of periods accurately forecasted			
		95%	90%	80%	50%
Maximum Error Magnitude	5%	0.76%	1.52%	3.42%	6.84%
	10%	0.76%	3.04%	3.80%	6.84%
	20%	1.52%	3.04%	4.18%	13.31%
	50%	4.18%	7.22%	16.35%	41.44%

Figure 6.5: Forecasting accuracy, worst error

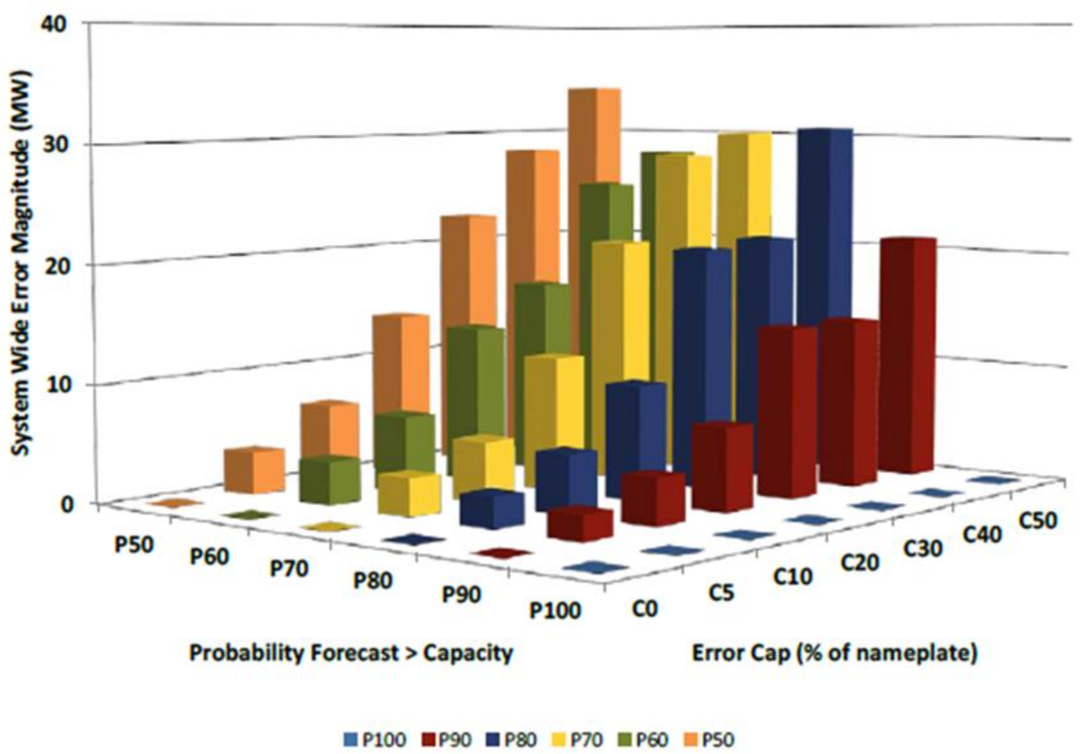


Figure 6.5 shows the system wide error that was simulated for different levels of solar forecast accuracy.

The proposed accuracy standard would deliver 90% of periods where forecast capacity is less than the actual capacity and a maximum error of 5% between the forecast and actual solar capacity. Table 2.1 indicates that forecast accuracy is estimated to breach the SSG about 1.5% of the time that solar generators are producing power. Figure 6.5 suggests the specified forecast accuracy will result in a system wide impact of a few MW.

Figure 4 was extracted from the supplementary consultation paper developed by PWC in March 2019, titled “framework for the future”. The figure presents an analysis of the size of imbalance between load and generation that could breach the frequency operating standard assuming no governor response. It shows that an imbalance of less than 3.75 MW, with no governor response available should not give rise to load shedding. This means that a cloud cover event that causes a net generation reduction of less than 3.75 MW and occurs concurrently with a generator contingency should not give rise to load shedding. 3.75 MW is aligns with the level of system wide error shown in Figure 6.5 for a solar forecast accuracy requirement achieving 90% of forecasts below the actual capacity and a maximum forecast error of 5%. This suggests that these accuracy requirements may be appropriate if cloud cover events are likely to align with generator contingencies in the NT power systems.

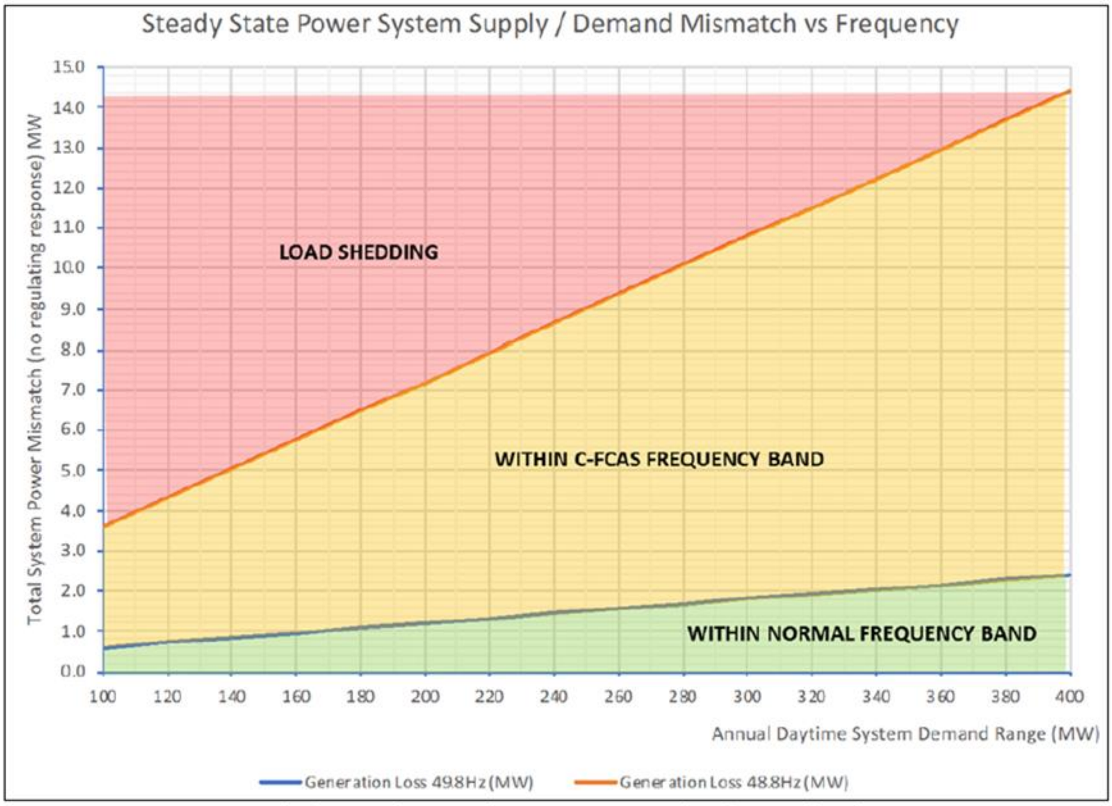


Figure 4 - Power Supply / Demand Mismatch vs System Demand and Unregulated Frequency Impacts

The thermal generation fleet supplying the DKIS currently experience a high number of forced outages (98 occurred over a 12 month period in 2017/18). On that basis PWC have asserted that it is reasonable to assume cloud events and generator outage may occur at the same time. PWC appear to have assumed that the available governor response would be called upon to address the generator contingency and it is therefore necessary to limit the size of the forecast error due to a cloud cover event such that load shedding is not triggered assuming no governor response. This approach appears to be reasonable as it seeks to establish a forecast accuracy requirement that maintains the current risk of load shedding for customers. GHD is therefore satisfied that the proposed generator performance standard with recommended changes is appropriate, as it seeks to impose an accuracy requirement sufficient to maintain existing levels of reliability of supply for customers connected to NT power systems.

GHD recommends the wording in section 3.22.3 be adopted.

3.22.3 Recommended Wording

(a) In this clause 3.3.5.17, the following terms apply:

(1) ‘t’ is time.

(2) ‘t=0’ refers to the moment when a forecast is updated.

(3) 't=[numeral]' refers to the number of minutes elapsed since t=0.

(4) 'capacity' means the minimum capability of a *generating system* to deliver an active power output at a continuous steady level over the relevant 5 minute interval.

(5) 'firm offer' means the capacity forecast provided at t=0 for the interval commencing t=0 for 5 minutes

(6) 'dispatch capacity' means the capacity instructed to the *Generator* to be injected into the grid.

(7) 'actual capacity' means the minimum instantaneous power injected into the grid for the interval commencing t=0 for 5 minutes.

(b) The capacity forecasting automatic access standard is:

(1) Subject to paragraph (f), a *Generator* must supply to the *Power System Controller* a forward forecast of the capacity of its *generating system*.

(2) The forecast in 3.3.5.17(b)(1) must:

(i) include a 24 hour ahead forecast for capacity for every 5 minute interval, updated at 5 minute intervals; and

(ii) have an accuracy such that in any rolling 24 hour period, at least 90% of the non-zero forecasts for the intervals commencing from t=5 to t=30 do not exceed the firm offer for the time for which the forecast was made.

(3) For every forecast assessed in paragraph (2)(ii) above, that exceed the firm offer, the forecast must not exceed the firm offer by a margin greater than:

(i) 5% of the *generating unit's* nameplate rating; or

(ii) 1 MW,

whichever is the lesser.

(4) The actual capacity must be within +/- 0.5% of the dispatch capacity.

Note: When issuing dispatch instructions, the System Controller will respect plant limits such as firm offers and ramp rates of plant.

(c) A *Generator* must provide forecasts to the *Power System Controller* in a format specified by the *Power System Controller*.

(d) The *generating system* owner will be required to report compliance against the above requirements in a format and timeframe determined by the *Power System Controller*.

(e) In the event of non-compliance with the automatic access standard by a *Generator*, the *Power System Controller* may adjust that *Generator's* subsequent forecasts and firm offers accordingly.

(f) Forecasts may differ from the firm offer, and actual capacity may differ from the dispatch capacity, as a result of actions to correct system frequency in accordance with other provisions of this *Code*.

(g) The *Network Operator* must publish a procedure that specifies the process the *Network Operator* will use to detect any non-compliance with the capacity forecasting performance standard and the process that will be used to determine the action taken in response to any non-compliance with that performance standard. The procedure must be published by 31 January 2020.

3.23 NTC Clause 3.3.6 – Monitoring and Control

3.23.1 Wording proposed by PWC

Remote Monitoring and Control

(a) The remote monitoring standard is:

(1) The *Network Operator* will require users to provide remote monitoring equipment ("RME") to enable the *Network Operator* and the *Power System Controller* to remotely monitor performance of a *generating unit* (including its dynamic performance) where this is reasonably necessary in real time for control, planning or security of the power system; and

(2) Any RME provided, upgraded, modified or replaced (as applicable) shall conform to an acceptable standard as agreed by the *Network Operator* and shall be compatible with the *Network Operator*'s SCADA system and the nomenclature standards of the *Network Operator* and as agreed to by the *Power System Controller*

(3) Input information to RME may include, but not be limited to, the following:

(i) Status indications:

a. Generating Unit Circuit Breaker Open/Closed
b. Remote Generation Load Control on/off
c. Generating Unit Operating Mode
d. Governor Limiting Operation
e. Connection to the network

(ii) Alarms:

a. Generating Unit Circuit Breaker Tripped by Protection
b. Prepare to off load

(iii) Protection Defective Alarms

(iv) Measure Values:

a. Gross active power output of each *generating unit*
b. Net station active power import or export at each connection point
c. Gross reactive power output of each *generating unit*
d. Net station reactive power import or export at each connection point
e. *Generating unit* stator voltage
f. *Generating unit* transformer tap position
g. Net station output of active energy (impulse)
h. *Generating unit* remote *Generation* control high limit value
i. *Generating unit* remote *Generation* control low limit value
j. *Generating unit* remote *Generation* control rate limit value
k. For energy storage devices the available energy (in MWh)
l. *Generating unit* present maximum active capacity
m. *Generating unit* forecasted maximum active capacity

(v) Such other input information reasonably required by the *Network Operator or Power System Controller*.

(4) A User is required to install remote control equipment ("RCE") that is adequate to enable the *Power System Controller* to remotely control:

(i) The active power output of any *generating unit*; and

(ii) The reactive power output of any *generating unit*.

(5) Unless agreed otherwise, the relevant User will be responsible for the following actions at the request of the *Network Operator* or the *Power System Controller*:

(i) Activating and de-activating RCE installed in relation to any *generating unit*; and

(ii) Setting the minimum and maximum levels to which, and a maximum rate at which, the *Power System Controller* will be able to adjust the performance of any *generating unit* using RCE.

(6) A User shall provide electricity supplies for the RME and RCE installed in relation to its *generating unit* capable of keeping these facilities available for at least eight hours following total loss of supply at the connection point for the relevant *generating unit*.

(7) The performance of the RME and RCE in terms of accuracy and reliability shall meet the requirements of the *Network Operator* and *Power System Controller*.

(2) <u>Communications Equipment</u>

(a) The communications equipment standard is:

(1) A User shall provide communications paths (with appropriate redundancy) between RME or RCE installed at any of its *generating units* to a communications interface at the relevant power station and in a location reasonably acceptable to the *Network Operator*.

(2) Communications systems between this communications interface and the relevant control centre shall be the responsibility of the *Network Operator* unless otherwise agreed,

(3) The User shall meet the cost of the communications systems, unless otherwise determined by the *Network Operator*.

(4) Telecommunications between the *Power System Controller* and *Generators* shall be established in accordance with the requirements set down below for operational communications.

(i) Primary Speech Facility

(A) Each User shall provide and maintain equipment by means of which routine and emergency control telephone calls may be established between the User's responsible Engineer/ Operator and the *Power System Controller*.

(B) The facilities to be provided, including the interface requirement between the *Power System Controller*'s equipment and the User's equipment shall be specified by the *Network Operator*.

(ii) Back-up Speech Facility

(A) Where the *Network Operator* advises a User that a back-up speech facility to the primary facility is required, the *Network Operator* will provide and maintain a separate telephone link or radio installation. The costs of the equipment shall be recovered through the charge for connection.

(B) The *Network Operator* shall be responsible for radio system planning and for obtaining radio licenses for equipment used in relation to the *Network Operator* networks.

3.23.2 Observations and Issues Identified

There is no automatic standard defined in the proposed wording for clause 3.3.6 of the NTC, rather a single set of technical requirement is provided stating the generator parameters that need to be monitored and/or controlled by the Network Operator and Power System Controller and the required communications systems. The NER NT specifies automatic and minimum access standards. The requirements specified by PWC are consistent with the automatic access standard in the NER NT.

The NTC requires remote monitoring and control to continue to operate for 8 hours after total loss of supply – the NER NT requires 3 hours. The basis for longer time frame has been clarified with PWC as being justified by the typical restoration times following outages for NT power systems. GHD is therefore satisfied that no change to the wording proposed by PWC is required and that wording provides an appropriate balance between the cost imposed on generators and the system security benefit achieved.

3.24 NTC Clause 3.3.7 – Power Station Auxiliary Supplies

3.24.1 Wording proposed by PWC

In cases where a generating system takes its auxiliary supplies via a connection point through which its generation is not transferred to the network, the access standards for the auxiliaries must be established under clause 3.6 as a Load Customer.

3.24.2 Observations and Issues Identified

The proposed wording for this clause is totally consistent with the NER NT clause S5.2.7. It is recommended that the proposed drafting be accepted.

3.25 NTC Clause 3.3.8 – Fault Current

3.25.1 Wording proposed by PWC

(a) The fault current standard is:

(1) The contribution of the generating system to the fault current on the connecting network through its connection point must not exceed the contribution level that will ensure that the total fault current can be safely interrupted by the circuit breakers of the connecting network and safely carried by the connecting network for the duration of the applicable breaker fail protection system fault clearance times, as specified for the relevant connection point by the *Network Operator*;

(2) A generating system's connected plant must be capable of withstanding fault current through the connection point up to the higher of:

(i) The level specified by the *Network Operator*; or

(ii) The highest level of current at the connection point that can be safely interrupted by the circuit breakers of the connecting network and safely carried by the connecting network for the duration of the applicable breaker fail protection system fault clearance times, as specified by the *Network Operator*.

(3) A circuit breaker provided to isolate a generating unit or generating system from the network must be capable of breaking, without damage or restrike, the maximum fault currents that could reasonably be expected to flow through the circuit breaker for any fault in the network or in the generating unit or generating system, as specified in the *connection agreement*.

3.25.2 Observations and Issues Identified

The wording proposed by PWC for this clause is consistent with the automatic access standard of the NER NT (S5.2.8). Although no minimum access standard or negotiating guidance is specified in the NTC, those provisions in the NER NT would be difficult to apply and, as such, no change to the proposed drafting is recommended.

3.26 NTC Clause 12 – Transitional Arrangements and Derogations

3.26.1 Wording proposed by PWC

12.1 Purpose and application

(a) This clause 12 prevails over all other clauses of this *Code*.

(b) *Derogation*s of *Users* are:

(1) those provisions of the other clauses of the *Code* which shall not apply either in whole or part to particular *Users* or potential *Users* or others in relation to their facilities for a fixed or indeterminate period;

(2) any provisions which substitute for those provisions which are not to apply; and

(3) applicable only to that particular *User* or potential *User*.

(c) *Derogation*s are for the purpose of:

(1) enabling *Users* to effect an orderly transition to the provisions of the *Code* from those provisions currently applying (including extension of a grace period set out in Schedule S4);

(2) providing specific exemptions from the *Code* for pre-existing arrangements which the *Network Operator* determines shall continue beyond a specific transition period; and

(3) providing specific exemptions from the *Code* for future arrangements (implemented after the introduction of a new version of this *Code*) that the *Network Operator* determines to be acceptable.

(d) The *Network Operator* is not required to grant a *derogation* if doing so will adversely affect *network capability*, *power system security*, quality or reliability of *supply*, *intra-regional power transfer capability* or the use of a *network* by another *User.*

(e) An applicant for a *derogation* must submit that application in such form reasonably required by the *Network Operator* which application must outline:

(1) the nature of the *derogation* sought;

(2) why the *derogation* should be granted;

(3) why granting of the *derogation* will not have the effect referred to in clause 12.1(d).

(f) Applications for *derogations* under clause 12.1(b)(1) and (2) may be granted if the *Network Operator* in good faith forms the view that the *derogation* is appropriate given the pre-existing arrangements to which the *User* is party and having regard to the criteria in clause 12.1(d).

(g) In considering applications under clause 12.1(b)(3) the *Network Operator* must apply the principle that *Users* first applying to *connect* to the *electricity network* after the commencement of version [4] of this *Code* should comply with the standards in this *Code* and that *derogations* should only be granted to small *Users* who have only minor impact upon the *electricity network* (including when their impact is aggregated with other small *Users*) or where there are otherwise compelling reasons for granting the *derogation*.

(h) Applications for *derogation*s shall be submitted to and processed by the *Network Operator* in accordance with any requirement of applicable laws-.

12.2 Pre 1 April 2019 plant and equipment

(a) This clause applies to *plant* of a *Generator User connected* to the *electricity network* prior to 1 April 2019 (such *plant and equipment* being ***Existing Connection Plant***).

(b) A *Generator User* to whom this clause applies must, in respect of the *Existing Connection Plant*:

(i) comply with the technical standards applicable to such *Existing Connection Plant* under Version 3 of this *Code* (as in force immediately prior to the date Version 4 of this *Code* came into effect); and

(ii) comply with clause 3 of this *Code* (Technical requirements for equipment *connected* to the *network*) including the *automatic access standards* set out in that clause 3 to the extent the *Existing Connection Plant* is able (without requiring modification, alteration or enhancement) to comply with that clause and those *automatic access standards*.

(c) A *Generator User* to whom this clause applies must, if required by the *Network Operator*, conduct such tests as required by the *Network Operator* to determine the extent to which the *Existing Connection Plant* of the *Generator User* is able to comply with clause 3, including the *automatic access standards*. Such tests must be conducted at the times and otherwise in accordance with the requirements reasonably determined by the *Network Operator*.

(d) The *Generator User* must report the results of the tests to the *Network Operator* in such manner specified by the *Network Operator* acting reasonably.

(e) The *Generator User* must bear its own costs of undertaking the tests required by the *Network Operator* and must reimburse the *Network Operator*, at such times reasonably determined by the *Network Operator*, the *Network Operator's* reasonable costs of conducting and overseeing such tests.

(f) If a *Generator User* materially modifies, alters or enhances *Existing Connection Plant*, then it must do so in accordance with any applicable provisions of the *NT NER* and this *Code* (including where required by this *Code* complying with the *automatic access standards* or such *negotiated access standards* as may be agreed).

12.3 Post 1 April 2019 plant and equipment

(a) This clause applies to a *Generator User* who has entered into a connection agreement with the *Network Operator* prior to Version 4 of this Code coming into effect but had not completed the *connection* of *plant and equipment* to the *electricity network* prior to 1 April 2019.

(b) Subject to this clause 12.3, such *Generator User* must ensure all *plant and equipment connected* to the *electricity network* pursuant to that *connection agreement* complies with the requirements of this *Code* including (subject to paragraph (c) below) the *automatic access standards.* However where a grace period for a technical requirement is specified in Schedule S4 a *Generator User* will not be regarded as in breach of this *Code* if:

(i) within 30 days of commencement of version [4] of this *Code* it submits to the *Network Operator* a written communication confirming each *automatic access standard* that is met, and for each individual *automatic access standard* that is not met, a plan setting out the procedures, consistent with *good electricity industry practice*, which will be followed by the *Generator User* to ensure it complies with that technical requirement from the end of the applicable grace period; and

(ii) it complies with that plan; and

(iii) it ensures it complies with that technical requirement as soon as reasonably practicable and in any event from the end of the relevant applicable grace period.

(c) A plan submitted under clause 12.3(b):

(i) may include a process for negotiating a *negotiated access standard*; and

(ii) must include the testing and commissioning procedures which will be followed by the *Generator User* to establish it has achieved compliance with each relevant technical requirement.

(d) A *Generator User* must make such changes to a plan submitted under clause 12.3(b) as reasonably required by the *Network Operator*.

(e) A *Generator User* to whom this clause applies may request the *Network Operator* to agree with it a *negotiated access standard* in substitution for an *automatic access standards* and, if so, the *Network Operator* will negotiate in good faith with the *Generator User* to agree such *negotiated access standard* in accordance with the criteria set out in clause 3.3.5. The *Generator User* must, at such times reasonably determined by the *Network Operator*, reimburse the *Network Operator* its reasonable costs of undertaking any such negotiations. Until such time as a *negotiated access standard* is agreed, any *connected plant* of the *Generator User* must, subject to clause 12.3(b), comply with the *automatic access standard*.

(f) Where this *Code* contemplates a matter being agreed between the *Network Operator* and the *Generator User* and such matter is not specified in the *connection agreement* then:

(i) the *Network Operator* may, as a condition to connecting the *plant* to the *electricity network* and permitting its commissioning, require that the *Network Operator* and the *Generator User* agree such matters and document them as an amendment to the connection agreement; or

(ii) if the *plant* is already *connected* and commissioned as at the time Version 4 of this *Code* comes into effect, the *Generating User* must, if required by the *Network Operator*, negotiate in good faith to agree and document such matters by an amendment to the *connection agreement* (and if such matters are not agreed within 4 months of the *Network Operator's* request then the matter may be referred for determination by the *Utilities Commission* under clause 1.6(b)).

(g) The *Generator User* must, at such times reasonably determined by the *Network Operator*, reimburse the *Network Operator* its reasonable costs of negotiating and documenting the matters referred to in clause 12.3(f).

(h) The *Generator User* must report the results of the tests conducted in accordance with a plan referred to in clause 12.3(b) to the *Network Operator* in such manner specified by the *Network Operator* acting reasonably. The *Generator User* must bear its own costs of undertaking such tests and must reimburse the *Network Operator*, at such times reasonably determined by the *Network Operator*, the *Network Operator's* reasonable costs of conducting and overseeing such tests.

3.26.2 Observations and Issues Identified

These clauses accommodate existing generators as follows:

- Generators connected before 1st April 2019 – May use version 3 of the code and must assess their ability to meet clause 3 of version 4 of the NTC via testing where necessary. There is no requirement to meet clause 3 automatic standards if this requires modification, alteration or enhancement to existing plant and equipment. This process does not actually result in a GPS being defined for existing plant.
- Generators connected post 1st April 2019 – Are allowed a grace period of between 30 days and 13 months to comply with the requirements of version 4 of the NTC. A process to achieve compliance with in the grace period is specified, which allows for negotiation of agreed GPS during the grace period specified in schedule S4. The proposed grace periods seem reasonable as longer periods are allowed for those performance standards that differs significantly from the technical requirements in version 3.1 of the NTC.

This approach is acceptable and consequently no changes to the wording of this clause are recommended other than to correct a typographical error in NTC clause 12.3(e) the revised clause is shown in section 3.26.3.

3.26.3 Recommended wording

12.3 Post 1 April 2019 plant and equipment

(e) A *Generator User* to whom this clause applies may request the *Network Operator* to agree with it a *negotiated access standard* in substitution for an *automatic access standard* and, if so, the *Network Operator* will negotiate in good faith with the *Generator*

User to agree such *negotiated access standard* in accordance with the criteria set out in clause 3.3.5. The *Generator User* must, at such times reasonably determined by the *Network Operator*, reimburse the *Network Operator* its reasonable costs of undertaking any such negotiations. Until such time as a *negotiated access standard* is agreed, any *connected plant* of the *Generator User* must, subject to clause 12.3(b), comply with the *automatic access standard*.

3.27 Alignment with SCTC

3.27.1 Observations and Issues Identified

SCTC 3.11.1 Forecasts – 3.11.1 in SCTC required generators to submit half hourly 30 day ahead generation capability forecast. During the interview with PWC it was confirmed that as there is no accuracy requirement associated with this forecast it is appropriate for the provision to remain in the SCTC rather than be combined with the forecast accuracy performance standard specified in clause 3.3.5.17 of the NTC.

4. Key findings

The key findings from our review can be summarised by answering each of the following questions:

- Is there a compelling need to introduce GPS across NT power systems at this time?
- Are the GPS proposed by PWC the appropriate set of standards for NT power systems?

Our key findings are presented in the following sections.

4.1 The case for introducing GPS across NT power system

Several stakeholders have raised concerns in their submissions to PWC that the introduction of the proposed GPS to NT power systems is not justified or that it is not necessary to make the proposed changes at this point in time. The submissions cite a number of concerns including:

- the cost of complying with the automatic access standard proposed for a number of technical requirements in particular the forecast accuracy required proposed in NTC clause 3.5.17 threatens the commercial viability of new solar generation projects
- the forecast accuracy requirement prevents the adoption of other more efficient measures such as central batteries shared by a number of generators
- the forecast accuracy requirement is difficult to meet for generators developed behind the meter and operating with a zero-export connection agreement
- renewable generators may be constrained to provide frequency control services suffering lost revenue from energy sales

As discussed in section 3.22.2, GHD agrees that further clarity regarding the manner in which PWC will assess and respond to any failure to meet the forecast accuracy requirements is essential to allow generators to assess the investment required to achieve an appropriate level of compliance. However we believe that with that information available it should allow generators to develop the most efficient solution for meeting the accuracy requirements and where appropriate build the case if necessary to negotiate alternate performance standards.

GHD has considered the case for introducing GPS and we believe that the introduction of an appropriate GPS framework is justified at this time. We note that the proposed framework does allow for generators to negotiate alternate performance standards if they can demonstrate that adopting those standards does not adversely affect power system security or the quality of supply to *Network Users*. The revisions that we have suggested to the proposed GPS framework should facilitate generators who wish to negotiate a performance standard to build the necessary arguments and evidence.

The NT power systems like many across Australia and around the world are undergoing a period of significant change driven by the desire to reduce greenhouse gas emissions, while balancing affordability and reliability. In the NT significant growth in the amount of generation from solar power is expected in the near term. PWC have identified that over 120 MW of new solar generation has applied to connect to the DKIS[6]. The NTC currently includes generator technical requirements that are largely written for a power system with a generation fleet dominated by gas fired synchronous generators. Those technical requirements need revision to remove technology bias and provide requirements that are applicable for

[6] PWC application to the Utilities Commission, page 18.

future power systems incorporating significant levels of renewable generation such as large scale solar PV power stations.

Adopting a GPS framework in the NT power systems is consistent with reforms either recently completed or underway in other power systems across Australia. In September 2018 the Australian Energy Market Commission[7] completed a review of generator performance standards for the NEM. In Western Australia reforms are underway to replace the technical requirements for transmission connected generators participating in the Wholesale Electricity Market (WEM) with a GPS framework. The new GPS framework will be specified in the WEM Rules replacing the requirement currently specified in the Western Power Technical rules. In 2018 Western Power and AEMO developed a generator performance guideline describing the proposed arrangements[8] which leverage the work undertaken by the AEMC.

By specifying appropriate performance requirements for all significant generators, a GPS framework provides greater certainty over the technical capability of the power system particularly as the generation mix evolves to include greater levels of solar generation. In the absence of a GPS framework uncertainty in generation performance leads to uncertainty in the system operator's assessment of system capability, which is likely to lead to either:

- Conservative operating limits leading to constraints on solar generation, or
- Unexpected insecure operation, risking customer load shedding.

PWC has proposed that the GPS framework apply to all generators exceeding 2 MW. Given the size of the NT power systems GHD considers this threshold is appropriate.

4.2 Are the GPS proposed by PWC appropriate for NT power systems?

The majority of the technical performance requirements proposed by PWC for the NT power systems reflect the equivalent provisions in the NER NT. The proposed performance standards therefore leverage the insights gained through the AEMC assessment of generator performance standards completed in September 2018.

Some of the performance standards proposed by PWC differ from those applicable in the NEM. With the revisions made reflecting appropriate changes to align with current technical requirements. We have reviewed the basis for those differences and found that the changes proposed are appropriate given the technical characteristics of the NT power systems and the key differences between the NT power systems and those in the NEM.

The following aspects of the GPS proposed by PWC are quite different to those in the NEM:

- the GPS specifying minimum capacity forecast accuracy requirements (NTC Clause 3.3.5.17). There is no such requirement in the NEM. PWC has identified that the relatively high probability of thermal generation failures in the NT power systems means that it is reasonably probable for cloud cover events and the resulting forecast errors to occur at the same time as generator failures. The capacity forecast accuracy requirements are a reasonable approach to minimise the risk of cloud cover events yielding forecast errors. The accuracy requirements have been selected so that even with increased levels of solar generation there should be no deterioration in supply reliability. As

[7] https://www.aemc.gov.au/rule-changes/generator-technical-performance-standards

[8] https://westernpower.com.au/media/3226/generator-performance-guideline.pdf

discussed in section 3.22.2, PWC has selected accuracy thresholds that should deliver supply reliability at historical levels.

The key area of concern with the capacity forecast performance standard is that there is no documented procedure available that describes how PWC intends to assess compliance and the sanctions PWC will impose for compliance breaches. Without this information generation developers will find it very difficult to make appropriate commercial decisions regarding the efficient investment required to meet the performance requirements. GHD has therefore recommended a change to the NTC to require PWC to document this procedure.

- the requirement for permanently enabled frequency response capability (NTC Clause 3.3.5.11) and inertia and contingency FCAS capability (NTC clause 3.3.5.15). These GPS provision impose mandatory frequency response capability whereas the NER only requires generators provide such capability be provided if dispatched to provide ancillary services. GHD has proposed amending the GPS to clarify that the response requirements are subject to energy source availability. That change coupled with drafting included in the SCTC makes it unlikely that PWC will constrain renewable generators to maximise the raise response they deliver following generator contingencies.

  GHD believes that the proposed performance standards are appropriate for the isolated NT power systems. The performance standards will in effect require renewable generators to contribute frequency control subject to energy source availability. This approach reflects good electricity industry practice which has been adopted in a number of grid codes around the world. It reflects the approach proposed in the generator performance standards for the SWIS developed by AEMO and Western Power. It is also consistent with rule changes proposed for the NEM that are currently being considered by the AEMC. Those changes to the NER seek to reintroduce a mandatory requirement for all generators to provide primary frequency response[9]. The GPS as proposed should not impose a significant cost on renewable generators but will provide for more efficient control of frequency in the NT power systems.

GHD has recommended a number of revisions to the proposed GPS to clarify the performance requirements which will allow generators to identify efficient options for meeting the specified performance standards and where appropriate negotiate alternate standards that lead to more efficient investment while delivering similar power system security and quality of supply outcomes. We therefore recommend implementing the proposed GPS with the recommended revisions described in this report.

[9] The AEMC is currently considering three rule change proposals that seek to improve frequency control in the NEM by reinstating a mandatory requirement for all generators to contribute primary frequency response https://www.aemc.gov.au/sites/default/files/2019-09/Primary%20frequency%20response%20rule%20changes%20-%20Consultation%20paper%20-%20FOR%20PUBLI....pdf

Level 9 145 Ann Street Brisbane QLD 4000 Australia GPO Box 668 Brisbane QLD 4001 Australia

61 7 3316 3000
advisory@ghd.com

https://projectsportal.ghd.com/sites/pp07_02/utilitiescommissiono/ProjectDocs/Deliverables/GHD Report - review of proposed GPS.docx

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