Transgrid

Connection Application Guideline

11 November 2026



Document Control

Table 1-1 Document control

Version	Date	Details	Prepared by
0	2026-11-11	Initial release	Transgrid Network Connections Team

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- connection applications, enquiries or agreements relating to new connections, or modifications to existing connections, made or entered into by other parties;
- changes to the NER, other applicable laws or regulatory requirements, or the requirements of Australian Energy Market Operator (AEMO); and
- the impacts of any technical requirements of other network service providers (including without limitation any special protection schemes implemented by those other networks) of which Transgrid is not aware.

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Acronyms and definitions

Term	Definition	Remarks
AAS	Automatic Access Standard	
ADC	Aggregated dispatch conformance	
AEMO	Australian Energy Market Operator	
AVR	Automatic Voltage Regulator	
BESS	Battery energy storage system	
CA	Connection Application	
CER	Connection Enquiry Response	
CP	Connection Point	
CPA	Connection Process Agreement	
CPM	Commercial Proposal Manager	
CPTSR	Connection Point Technical Specification Report	
CSR	Connection Study Report	
CT	Current Transformer	
CUO	Continuous Uninterrupted Operation	Defined in the NER Glossary
DMAT	Dynamic Model Acceptance Test	
DNA	Dedicated network asset	
DUID	Dispatch Unit Identifier	
EMT	Electromagnetic transient	
FAT	Factory acceptance test	Plant testing in the OEM factory
FCAS	Frequency Control Ancillary Services	
FRT	Fault Ride Through	
GFL	Grid Following	

Term	Definition	Remarks
GFM	Grid Forming	
GPS	Generator Performance Standard	
GS	Generating System	
GU	Generating Unit	
HVRT	High Voltage (Fault) Ride Through	
IUSA	Identified user shared asset	Defined in the NER Glossary
kV	Kilovolts	
LDC	Line drop compensator	
LVRT	Low Voltage (Fault) Ride Through	
MAS	Minimum Access Standard	
MFRT	Multiple Fault Ride Through	
MMIB	Multiple Machine Infinite Bus	
MW	Megawatts	
MVA	Mega Volt-Amperes	
MVAr	Mega Volt-Ampere Reactive	
NAS	Negotiated Access Standard	
NEL	National Electricity Law	Available on the AEMC website
NEM	National Electricity Market	
NER	National Electricity Rules	Available on the AEMC website
OEM	Original equipment manufacturer	
OLTC	On load tap changer	Used to adjust a transformer tap position
OM	Operating manual	Transgrid operating document
OPDMS	Operations and Planning Data Management System	

Term	Definition	Remarks
P	Active Power	
PIA	Preliminary impact assessment	In relation to system strength
PPC	Power plant controller	Generating system or BESS high level control system.
PSCAD™/ EMTDC™	Power Systems Computer Aided Design / Electromagnetic Transient with Direct Current	Simulation software (EMT), also referred to as "PSCAD" in this guide.
PSMG	Power System Model Guidelines (AEMO)	
PSS®E	Power System Simulator for Engineering	Simulation software (RMS)
p.u.	Per unit	
Q	Reactive Power	
QNI	Queensland – NSW interconnector	
RACI	Responsible Accountable Consulted Informed	
RFI	Request for information	
RoCoF	Rate of change of frequency	
RUG	Releasable User Guide	
SCR	Short circuit ratio	
SLD	Single line diagram	
SSA	System Strength Assessment	PSCAD wide area studies for system strength full assessment (SSFA) or system strength stability assessment (SSSA)
SMIB	Single machine-infinite bus	A simplified representation of the power system as seen from the Connection Point.
SSIAG	System Strength Impact Assessment Guidelines	Guidelines maintained and published by AEMO.
SPS	Special Protection Scheme	
SSRS	System Strength Remediation Scheme	
SSC	system strength charge	

Term	Definition	Remarks
SSLF	System strength locational factor	
SSPA	System strength preliminary assessment	
SSQ	System strength quantity	
TAPR	Transgrid Annual Planning Report	
TOV	Transient Over-Voltage	
VCS	Voltage Control Strategy	
X/R	Reactance to resistance ratio	

Chapter 1

Your Guide to a faster, smoother assessment

Transgrid is working to make the connections process clearer, more consistent and more efficient. This Guide is one of several initiatives to improve the experience for customers. It provides clear requirements and expectations to help reduce rework, avoid unnecessary delays and support faster progress through the application process. Alongside this, we are working on risk based approaches to streamline connection pathways, while meeting the technical standards needed to maintain power system security and reliability.

1.1 Why use this Guide?

The Connection Application can be technically complex. Transgrid is taking steps to improve the efficiency of the connections process and reduce avoidable delays by providing clear upfront information and adopting consistent processes through this guideline.

Transgrid and AEMO need detailed technical information of your proposed connection, fit-for-purpose models, proposed performance standards and supporting assessments. Missing, incomplete or inconsistent information can result in further information requests, additional modelling and assessment, and repeated review cycles, increasing assessment time and costs.

This Guide takes you through the process of developing a Connection Application, from the information you'll receive and engagement activities we suggest before detailed assessments begin, through modelling, technical assessments and performance standards, to preparing and submitting the Connection Application package. It also explains how your application will be assessed and the key steps that follow submission.

The Guide is grounded in the requirements of the National Electricity Rules (NER) and draws on Transgrid's extensive experience working alongside AEMO and applicants on connection applications. It brings together established technical requirements, assessment methodologies and shared lessons from previous applications to provide practical, best-practice guidance from the start.

Using this Guide from the outset gives you a clear view of requirements, helps your submission progress smoothly through assessment, and supports a more transparent, predictable and efficient process for all parties.

1.2 Who is this Guide for?

This Guide is for applicants and their advisors seeking to connect to the Transgrid Network under the open access framework. Key users will be inverter-based resource (IBR) projects, including inverter-based asynchronous generating systems and Battery Energy Storage Systems (BESS)1. The Guide applies to the Connection Application phase, which is after the Connection Enquiry phase. Refer to the Network connections page of Transgrid's website for further information on the connections process.

1 Synchronous generator and large load connections are outside the scope of this guideline

1.3 What are the steps in the Connection Application Process?

Note: these steps take place **after** the connection enquiry phase.

Step 1: Start your application

When you submit a Notice to Apply for Connection to Transgrid, you will be assigned a Commercial Proposal Manager as your primary point of contact, who will work with you to establish the Connection Process Agreement (CPA).

Step 2: Get the network information you need

Once the CPA is executed, Transgrid will provide the network information you need to prepare your Connection Application, including a Network Data Pack and a Network Planning Supplementary Report (see Section 2) – and you'll have an opportunity to ask questions and engage with both Transgrid and AEMO.

Step 3: Prepare your Connection Application

Use the information you gathered to undertake the required technical studies and prepare your Connection Application package for submission. Your Commercial Proposal Manager will guide you through the process, but you are responsible for providing the required information and responding to requests from Transgrid and AEMO during the assessment.

Step 4: Due diligence by Transgrid and AEMO

Transgrid, in consultation with AEMO, will assess the Connection Application to ensure your project meets the technical and performance requirements of the NER. This will include negotiating performance standards and assessing system strength requirements.

Step 5: Obtain connection approvals

Once the assessment is complete, including agreeing performance standards and completing the system strength assessment, Transgrid and AEMO will provide responses under clauses 5.3.4A and 5.3.4B of the NER.

Step 6: Progress to an Offer to Connect

Transgrid will issue you an Offer to Connect. Once the connection agreement is executed, and you and Transgrid have jointly notified AEMO (in accordance with the NER), your project becomes Committed.

Figure 1-1 shows the high-level stages and assessments of the Application to Connection process with additional detail provided in Figure 1-2.

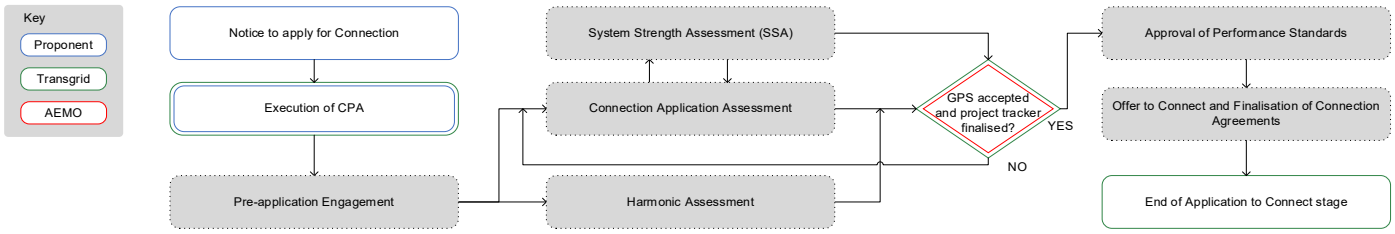


Figure 1-1: Overview of Connection Application process

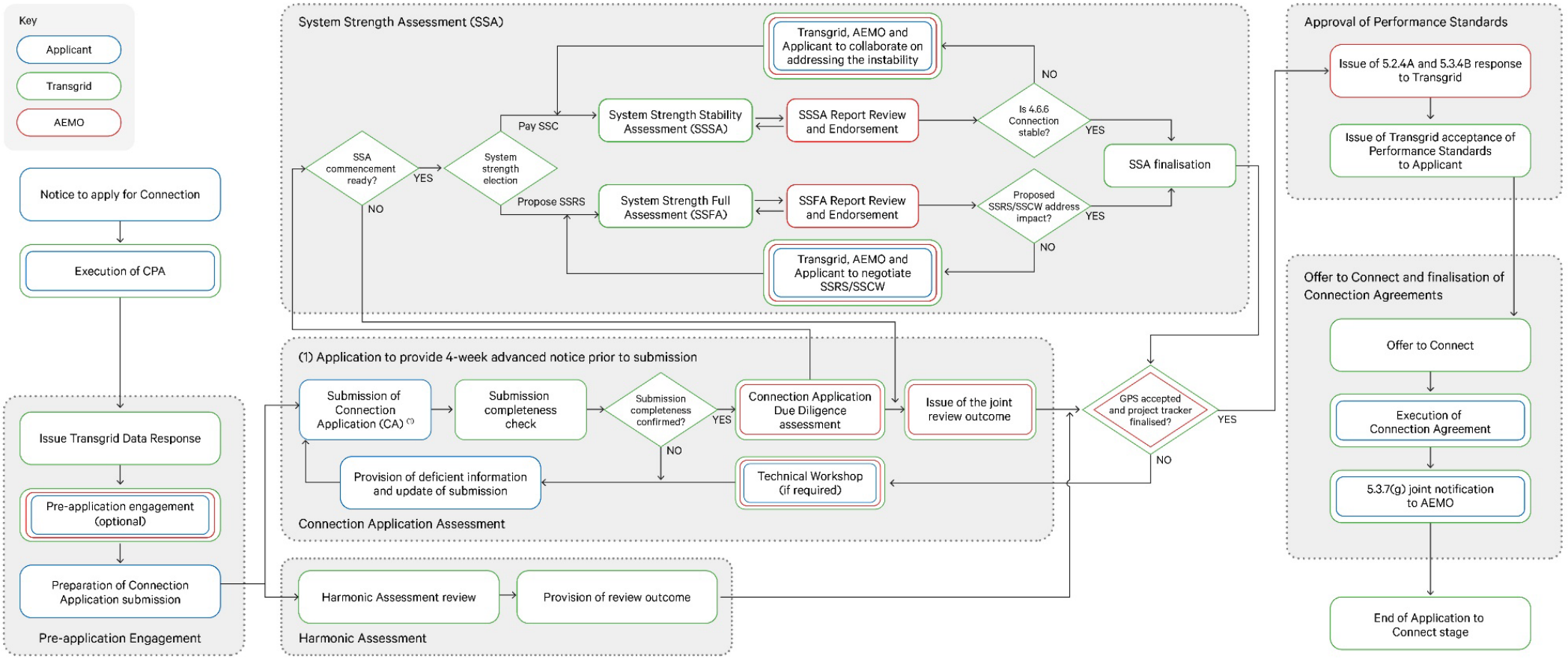


Figure 1-2: Connection Application process – key activities and assessments

1.4 How to use this Guide

Please use this Guide in conjunction with the National Electricity Rules (NER), AEMO guidelines and procedures, and project-specific information from Transgrid (see Section 2).

The remaining sections follow the chronological order of your Connection Application process. Consult it as you:

- Receive your network data – understand what information Transgrid will provide and your opportunities to ask questions and engage with Transgrid and AEMO before moving to design (Section 2)
- Develop your plant design and models – understand the design considerations and modelling requirements that support your application (Sections 3-4)
- Develop your performance standards – get advice on how to assess performance standards, including expectations and acceptance criteria and common submission mistakes (Section 5)
- Prepare and submit your application – discover what we expect your Connection Application package to contain, including additional guidance on areas where we often need to request more information from applicants (Section 6)
- Understand what happens next – sets out the assessment process and the key steps after submission (Sections 7-8)

Note: This Guide does not replace the requirements of the NER, AEMO procedures, applicable standards, or project-specific advice from Transgrid or AEMO. If you are unsure or the guidance appears inconsistent, follow the NER and other regulatory instruments.

Chapter 2

Preparing for a Connection Application

This section explains what information Transgrid will provide to help you prepare your Connection Application, how to access additional information or ask questions, and other matters to work through before submission.

2.1 Process overview

Figure 2-1 below shows the key stages in preparing a Connection Application.

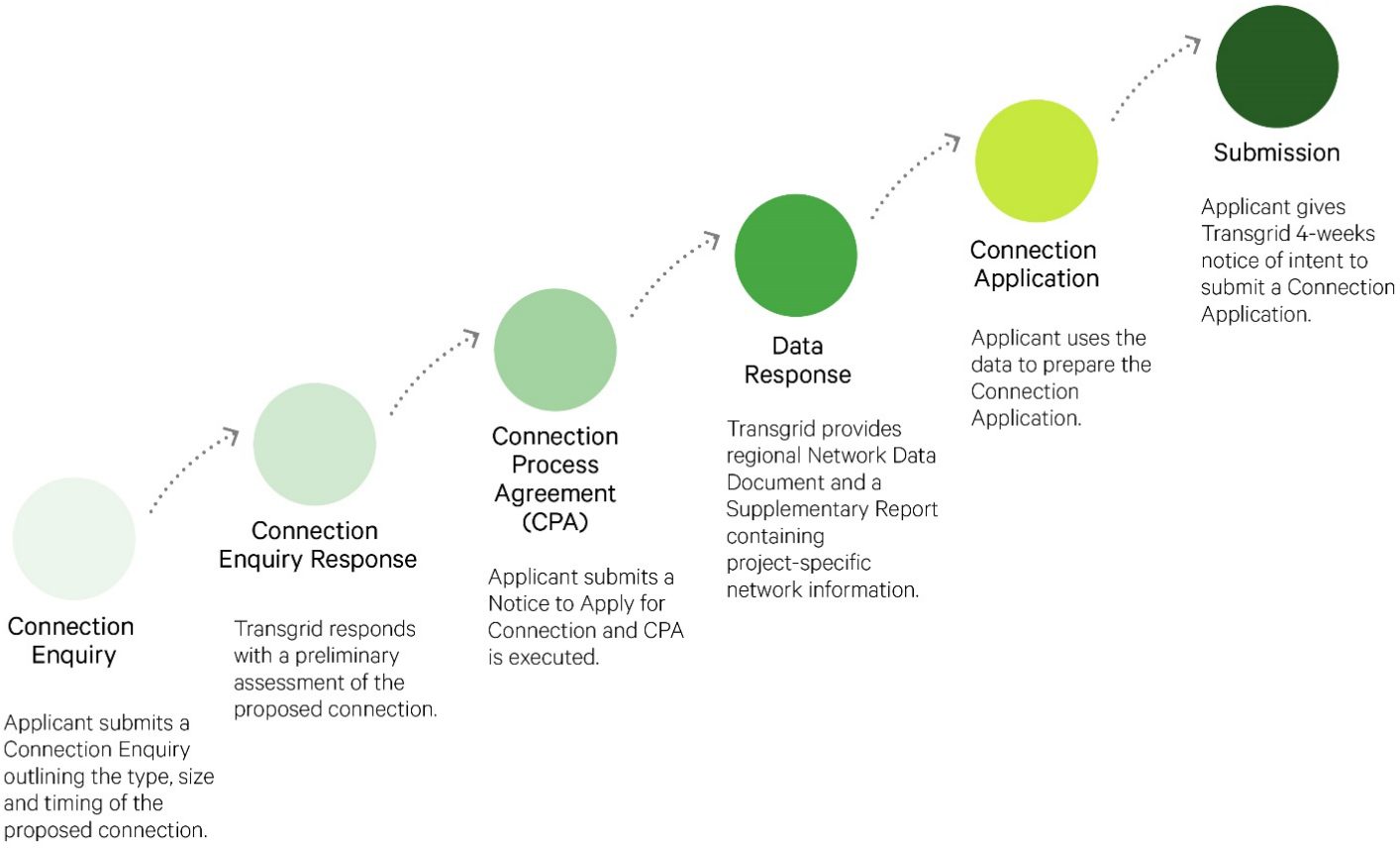


Figure 2-1 Process to prepare a connection package

2.2 What information is provided?

Transgrid will provide information at two key stages to help you prepare your Connection Application:

- Following your Connection Enquiry – you will receive a Connection Enquiry Response and supporting information (see Section 2.3)
- After the Connection Process Agreement (CPA) is executed – you will receive a Data Response with network information relevant to the location of your connection (see Section 2.4)

2.3 Connection enquiry response (CER)

Transgrid's CER includes:

- Connection Enquiry Response document
- Connection Point Technical Specification Report (CPTSR)
- System Strength Preliminary Assessment (SSPA), where applicable
- IUSA/DNA Specification, where applicable

2.3.1 CER document

The CER document provides a preliminary assessment of the proposed connection, including the:

- Proposed connection arrangement
- Power transfer capability of the proposed Connection Point
- Potential constraints and necessary augmentations
- Initial remedial action scheme requirements

2.3.2 Connection Point Technical Specification Report (CPTSR)

The Connection Point Technical Specification Report (CPTSR) sets out the project-specific technical requirements for matters where the applicable access standard or technical requirement is to be determined by Transgrid as the NSP. The key information typically included in the CPTSR is summarised in Table 2-1.

Table 2-1 Key information in the CPTSR

CPTSR contents	Description
NER S5.2.5.2 Quality of Electricity Generated	• Emission limits for: • Voltage fluctuations (flicker) and Rapid voltage change • Harmonic voltage emissions • Negative sequence voltage unbalance
NER S5.2.5.6 Quality of Electricity Generated and Continuous Uninterrupted Operation	• Quality of supply limits that a plant is expected to remain in Continuous Uninterrupted Operation: • Voltage fluctuation (flicker) • Harmonic voltage emissions • Negative sequence voltage unbalance
NER S5.2.8 Fault Current	• Allowable fault current contribution from the plant • Required fault level withstand capability

2.3.3 System Strength Preliminary Assessment (SSPA)

For inverter-based resource systems, Transgrid performs a System Strength Preliminary Assessment (SSPA) in accordance with clause 5.3.4B of the NER and AEMO's *System Strength Impact Assessment Guidelines* (SSIAG). The information in the SSPA includes:

- Nearest System Strength Node (SSN) and System strength locational factor (SSLF)
- Indicative system strength quantity (SSQ) and indicative system strength charge (SSC)
- Expected minimum available three phase fault level at the Connection Point2
- Reduction in available fault level (AFL), the materiality threshold for the system strength impact.

2.3.4 Identified User Shared Asset (IUSA) / Designated Network Asset (DNA) Planning Functional Specification

The IUSA/DNA Planning Functional Specification defines the scope of Transgrid's minimum planning, technical, operational and interface requirements for the proposed shared transmission assets. The information in the IUSA/DNA includes the:

- Proposed connection arrangement
- Identified User Shared Assets (IUSA) scope
- Non-Contestable Assets scope, if required
- Designated Network Asset scope, if any.

2 Use the minimum available fault level specified in the SSPA to determine the AFL reduction due to the proposed connection. However, do not use the minimum AFL for performance standards compliance assessments. Instead, use the fault level information in the Supplementary Report to assess GPS compliance.

2.4 Data Response

The Data Response includes the site-specific, regional and general information summarised in Table 2-2.

Table 2-2 Information provided in Transgrid Data Response

Site-specific information	Regional information	General Information
• Network Planning Supplementary Report (Section 2.4.1) • Harmonic impedance polygons (Refer to the Harmonic Assessment Requirements Guide in Section 4.7.1)	• Regional Network Data Document • Extracts of relevant Transgrid Operating Manuals (OMs) that describe the operation of the network within the relevant region • A spreadsheet with the details of the Special Protection Schemes (SPSs) in the relevant region • Transgrid harmonic assessment guide • Transgrid harmonic assessment for distorting load guide • Transgrid voltage control strategy (VCS) guide • Var dispatch specification • Transgrid transformer energisation study guide Further information is provided in Section 2.4.2.	• Transgrid commissioning package • Transgrid outage statistics • SSAT guideline

2.4.1 Supplementary Report

The Network Planning Supplementary Report provides site-specific data for your proposed Connection Point. The key information included in the Supplementary Report is summarised in Table 2-3.

Table 2-3 Key information in the Supplementary Report

Supplementary Report contents	Details
An overview of the connection arrangement	• Location of the Connection Point(s)
The fault level and X/R information at the Connection Point to be used for Performance Standards compliance assessments	• Minimum fault level / maximum system impedance • Typical fault level / typical system impedance (for system normal) • Maximum fault level
Voltage Control Strategy requirements	• The voltage control point may differ from the Connection Point based on the connection arrangement (discuss with Transgrid) • Historical voltage at the Connection Point
Any additional data required for the specific Connection Point	• For example, mid-point voltage, impedance data where there is a DNA

2.4.2 Regional Network Data Document

Regional Network Data Documents are standardised documents for each NSW region: Central, Central Coast, Central West, Greater Sydney, Northern and Southern. Each Regional Network Data Document contains detailed information of the transmission network in the relevant part of Transgrid's network, including:

- Single Line Diagrams
- Equipment ratings and electrical data for transmission lines and transformers
- Relevant electrical data for shunt reactors and capacitors, static var compensators and synchronous condensers
- Protection clearance times and auto recloser times
- Relevant N-1 contingencies to be considered for assessments
- List of local generation including in service, commissioning and committed plant
- References to other published information on planned or considered network augmentations
- Extracts from relevant Transgrid Operating Manuals describing operating arrangements, network protection schemes and generator special protection schemes
- Extracts from relevant Transgrid Operating Manuals outlining inter-regional and intra-regional power transfer limits, considering thermal ratings and transient, voltage and oscillatory stability limits
- The Regional Network Data Document also specifies the assessment criteria for thermal capacity, normal voltage range and allowable voltage step changes due to events.

Regional Network Data Documents, which you and your team can access through Transgrid ShareFile, are updated as the network evolves. Use the latest available version when preparing or updating your Connection Application. The Regional Network Data Document(s) you receive will depend on the connection location. If your connection is near a regional boundary, Transgrid may provide documents for more than one region. In this case, consider the information for each relevant region when preparing your assessments.

2.5 What Pre-Application support is available?

While preparing your Connection Application submission, initial feedback is available from Transgrid and AEMO on aspects of the proposed plant design, modelling approach, study assumptions or network information. Early engagement with Transgrid can help clarify requirements, identify potential issues and reduce avoidable rework during the assessment process.

At any point before submitting your Connection Application, you have the opportunity to:

- Seek further information or ask for clarification by submitting a RFI to your Transgrid Commercial Proposal Manager through the RFI process
- and/or
- Use AEMO pre-application support services – see the *AEMO Pre-application Support Guide*.

Please consider the need for pre-application support as soon as you receive the CER. Where these services are used, please agree the scope of support with Transgrid and AEMO before the engagement begins.

2.6 Early submission of the Harmonic Assessment

Please submit the harmonic assessment required under NER S5.2.5.2 as early as practicable and, where possible, before submitting the full Connection Application. This enables potential harmonic mitigation requirements to be identified at an early stage and allows any impacts on the plant's reactive power capability to be assessed.

Late inclusion of harmonic filters can result in a potential plant redesign to meet reactive power capability requirements and/or re-assessment of other impacted performance standards.

See Section 5.3 for further guidance on harmonic assessment.

2.7 Transitioning to new versions of the NER

The technical requirements for connection under the NER are subject to periodic amendment through the *Rule Change process under the National Electricity Law*. The assessments to support proposed performance standards for a new connection or an alteration under NER 5.3.9 must be performed with reference to the most recent version of the NER applicable at the time of the Connection Application submission.

When the AEMC amends the technical requirements for connection in the NER, it generally provides transitional arrangements for projects that are already progressing through the connection process. For the most recent changes to the technical requirements for connection,3 the following transitional arrangements apply as per NER 11.186.4.

- The old access standards (those that applied when the new Rule was introduced i.e., NER version 233 or before) will continue to apply to all connections that received a Connection Enquiry Response before the Commencement Date of 21 August 2025. However, you may choose to apply some or all of the new access standards for your connection, subject to approval by the NSP and AEMO for advisory matters.
- The new access standards (i.e. NER version 234 and after) will apply to connections that have not yet received a Connection Enquiry Response by the Commencement Date.

Notify Transgrid of your access standard intentions

If you wish to apply all the new access standards, you must give Transgrid written notice. Within 30 business days of receiving the notice, Transgrid will provide written details of the technical requirements relevant to the proposed plant.

If you wish to apply some, but not all, of the new access standards, your written notice must identify the new access standards you propose to apply. Transgrid will consult with AEMO on relevant AEMO advisory matters, and Transgrid or AEMO may request further information. Within 30 business days after the later of receiving your notice and receiving any requested further information, Transgrid will advise whether the proposed mix of new and old access standards is accepted.

If the proposed mix of new and old access standards is not accepted, you must notify Transgrid whether you wish to apply:

- All the old access standards
- All the new access standards or

3 Final Determination on "Improving the NEM access standards – Package 1", published on 22 May 2025, available at Improving theNEM access standards – Package 1 | AEMC.

- A different mix of old and new access standards.

If the proposed mix of new and old access standards is accepted, Transgrid will provide written details of the relevant technical requirements within 30 business days after notifying you of its acceptance. Any accepted mix remains subject to further review by Transgrid and AEMO as part of the due diligence after your Connection Application is submitted.

Chapter 3

Design requirements and considerations

This section outlines key design requirements and issues to consider when designing your plant and preparing a Connection Application. Early consideration of these matters can help avoid redesign and reassessment requirements and support a more efficient connection assessment process.

3.1 Voltage Control Strategy (VCS)

3.1.1 Transgrid's recommended voltage control strategy

Your Supplementary Report will include details of the recommended VCS and the nominated Voltage Control Point.

What you need to do

- Where the nominated Voltage Control Point specified is located on the HV side of a Transgrid substation and the Connection Point is located on the MV side:
  - include all relevant electrical plant and equipment between the Connection Point and the Voltage Control Point – the substation transformers and associated OLTC models, underground cables, overhead lines and substation reactive plant – in the submitted SMIB model.
  - set up the SMIB study to consider historical voltage profiles at both the Connection Point and the nominated Voltage Control Point, together with the applicable OLTC voltage setpoint.
- Where Connection Point differs from the nominated Voltage Control Point, or if the historical voltage data for the Connection Point is not provided, ask for guidance and additional information through the RFI process.

See Section 4.9.3 for further guidance on SMIB case setup.

3.1.2 Alternative voltage control location considerations

- To minimise implementation complexity and project delivery risk, design the plant in accordance with the recommended VCS and Voltage Control Point nominated in the Supplementary Report (preferred approach).
- If you intend to propose an alternative Voltage Control Point, such as controlling voltage at the HV side of the project's main transformer rather than at the Connection Point:
  - ensure the proposed alternative is at the same voltage level as the originally nominated Voltage Control Point
  - provide a clear justification for the proposed alternative, including why the recommended approach is not practical.

3.2 Plant Capacity and Physical Connection Arrangement

The size of the largest credible contingency is a key consideration in maintaining the security and reliability of the NEM. The current contingency limits are around 700 MW for generation trips and around 500 MW for load trips. During planned outages of certain line sections, multiple BESS units and generators may be at risk of tripping. As a result, FCAS constraints in the NEM will impose limits on their operation.

What you need to do

To avoid increasing the size of the largest credible contingency and the associated impacts on power system security, multiple feeders and physical connection points are required when connecting:

- Generating systems with a rated capacity exceeding 700 MW at the Connection Point or
- BESS with maximum demand exceeding 500 MW at the Connection Point

Multiple feeders and connection points ensure that the loss of a single connection asset, busbar, transformer or network element does not result in the simultaneous disconnection of the entire facility.

Your CER will include project-specific requirements and guidance on acceptable connection arrangements to support early consideration of plant connection arrangement.

3.3 Power Plant Controller (PPC) design considerations

A PPC malfunction can result in significant and rapid changes to a plant's active and reactive power, potentially impacting power system security and stability. While hardware redundancy can mitigate the risk associated with PPC hardware failures, in certain malfunction scenarios (for example, those caused by software anomalies or configuration errors) the switchover logic designed to respond to hardware failures may fail to activate. This can prevent automatic transfer of plant control to a redundant controller.

What you need to do

- To reduce the risk of a single point of failure affecting a large proportion of plant output, limit the aggregate installed capacity of production units controlled by an individual PPC to 350 MVA. This requirement applies to both uni-directional and bi-directional plants.
- For connecting plant with an installed capacity exceeding 350 MVA, use multiple PPCs to mitigate the risk of a single controller failure affecting the entire facility. If you are considering using a single PPC, submit your proposed design to Transgrid as soon as possible and obtain approval before proceeding.

3.4 Remedial Action Schemes

3.4.1 Runback schemes

Network congestion and thermal loading constraints are now managed through AEMO's dispatch processes via the National Electricity Market Dispatch Engine (NEMDE). The use of runback schemes to alleviate network congestion has been discontinued across Transgrid's network, due to increased system security concerns.

What you need to do

- Do not rely on runback schemes to address network congestion and thermal loading constraints associated with your proposed connection.

3.4.2 Transfer trip schemes (TTS)

Transfer trip operation may result in adverse system impacts, including rapid changes in power flows, which can lead to unacceptable voltage disturbances for nearby network users.

Transgrid will only consider a low Short Circuit Ratio (SCR) transfer trip scheme following a credible contingency event (N-1) where:

- The contingency results in an unacceptable low-SCR condition
- Studies demonstrate that a TTS is necessary to maintain system stability and security after all other feasible solutions have been exhausted; and modelAEMO approves the scheme.

Note: if the capacity of existing transfer trip schemes within the Transgrid network is already fully utilised, it may not be feasible to accommodate additional schemes.

Transfer trip schemes or other remedial action schemes are not appropriate solutions for static limitations, such as insufficient reactive power margin to support the transfer of the connecting plant's output.

What you need to do

- Design, size and tune your plant to operate stably and meet the performance standards for fault levels corresponding to system intact (N) and credible contingency (N-1) network conditions, as specified in the Supplementary Report.
- Do not rely on transfer-trip schemes to propose or demonstrate compliance with Performance Standards, unless agreed by both Transgrid and AEMO.
- Use the CER information to undertake early assessments and identify potential reactive power margin limitations. Early identification will help you to:
  - appropriately size the plant for the proposed network location;
  - understand the risk of constraints being applied under system normal conditions; and
  - investigate alternative solutions, such as increasing the plant's reactive power capability through equipment oversizing or installing additional reactive support equipment to support the desired power transfer to the network.
- While preparing the CA package, if your assessment identifies the need for a TTS, Transgrid must agree the proposed TTS before you finalise tuning and plant design. Ask your Transgrid CPM to connect you with the Network Planning and Network Connections teams for consultation. You will need to provide:
  - relevant studies specified in Section 3.4.2, where applicable.
  - OPDMS study results for credible contingency events (N-1) demonstrating the need for the TTS. This should typically include pre- and post-contingency fault levels at the plant connection point (CP) and nominated nearby system strength nodes, together with relevant study results.

3.4.3 the proposed TTS design, including the tripping arrangement (voltage level and sections to be tripped), post-contingency PPC parameters and dispatch considerations, circuit breakers proposed to initiate the TTS, estimated communication delays, and model implementation instructions. Anti-islanding schemes

Sometimes, following a contingency event, the part of the network to which a production system is connected becomes separated from the national grid and forms an island supplying load. In these circumstances, the plant must be automatically disconnected by a local or remote anti-islanding scheme.

What you need to do

- Use anti-islanding to protect the power system against voltage instability, extreme voltage fluctuations and large frequency deviations.

3.5 Submission of multiple connection applications for capacity considered under a Single CER

If you plan to submit multiple Connection Application Submissions covered by a single CER, you need to account for the requirements of the overall facility, even if individual plants will be developed in stages.

What you need to do

- Use the same fault levels specified for the common Connection Point in each application. The system strength does not change when one or more generating systems are offline.
- Allocate the overall facility limits between individual generating systems as per the guidance in the CPTSR. This includes limits for harmonic voltage emission, negative sequence voltage unbalance and fault current contributions.
- Confirm your proposed allocation with Transgrid before starting detailed studies or preparing Connection Application submissions if you are unsure how the limits should be shared. This will help to avoid unnecessary rework.

3.6 Metering design requirements and considerations

Metering arrangements serve different functions throughout the connection process, including market settlement, GPS compliance demonstration during commissioning, R2 model validation and ongoing compliance monitoring, and plant control.

What you need to do

- Design metering systems to meet the requirements of the NER, relevant AEMO procedures and Transgrid's connection requirements (see Table 3-1, which discusses meters specifically related to GPS performance).
- Contact AEMO and Transgrid's Protection and Metering Design team for further guidance on revenue and to check meter requirements.

Table 3-1 Requirements and functions of meter types

Meter Type	Description
Compliance meters	Should be installed at the Connection Point. Transgrid only accepts measurements obtained at the Connection Point for compliance demonstration, unless performance is proposed and assessed at an alternative location under the agreed GPS. Depending on the agreed performance standards, multiple compliance meters may be installed, such as at the Connection Point and other agreed locations as per the GPS. Transgrid does not provide measurements from its own metering systems to demonstrate compliance, except in limited circumstances where benchmarking against an applicant's metering may be required. For plant with several physical Connection Points with single PPC under single GPS, each physical Connection Point should be individually metered. Facilities should also be provided to obtain real-time total plant measurement. For plant with multiple PPCs under single GPS, each PPC output should be individually metered. Facilities should also be provided to obtain real-time total plant measurement. CT summation arrangements are acceptable to Transgrid for obtaining total quantities for compliance metering purposes. A design may be submitted with the application package for Transgrid to review
Control meters	Used by plant control system to regulate the voltage, active power and reactive power at the Connection Point, or at an alternative location as nominated by Transgrid in the Supplementary Report and specified in agreed GPS. Customer can select a suitable location to install control meters.

3.7 Dispatch Unit Identifier (DUID) Design considerations

DUID requirements are primarily driven by AEMO Registration requirements and can have a significant impact on plant design, control architecture and metering arrangements.

What you need to do

- Engage with AEMO early in the Connection Process to understand your project-specific DUID requirements.

If you are proposing multiple DUIDs:

- Provide a high-level operational and control philosophy for the facility, together with a preliminary single-line diagram identifying:
  - connection point(s)
  - active power control point(s)
  - Voltage Control Point
  - CT and VT arrangements

- proposed DUIDs
- PPC arrangement.

This information will assist Transgrid in assessing the proposed plant architecture and identifying any connection, control, metering, or compliance considerations at an early stage of the connection process.

- Consider these design requirements:
- Continuous Uninterrupted Operation (CUO) compliance
- As CUO compliance must be demonstrated at the Connection Point, consider the implications of the proposed DUID arrangement and plant control strategy. Your design must demonstrate that CUO compliance can be maintained at the Connection Point under all relevant operating conditions.
- Aggregated Dispatch Conformance (ADC) participation

Hybrid facilities have the option to participate in ADC. See the *AEMO Fact Sheet on Aggregated Dispatch Conformance* for details.

3.8 Transformer Energisation Study

Transformer energisation can result in high inrush currents and associated voltage dips that may adversely affect the network and other network users. Early assessment and identification of these potential impacts can influence transformer selection, switching arrangements, energisation methodology, and any mitigation measures required to manage transformer energisation impacts.

What you need to do

To assess these impacts and identify relevant mitigation strategies:

- Undertake a transformer energisation study in accordance with Transgrid's *Attachment 1 - Transformer Energisation Guideline* in your Data Response – and include the report with your Connection Application submission package.
- If transformer data, connection arrangements, or energisation methodology are updated at the detailed design stage, review the study and, where necessary, repeat it as part of the Registration Capability Assessment.

Chapter 4

Modelling requirements

4.1 Overview

Your Connection Application includes plant models, which are required to assess and demonstrate the performance of a proposed connection against the access standard requirements. Models must comply with AEMO's *Power System Model Guidelines* and any additional specific requirements set out in this section.

Table 4-1 summarises the modelling platforms suitable for each access standard, based on the type of assessment required. See Section 5 for further guidance on the recommended modelling platform and scope for assessing each clause.

Table 4-1 Modelling platforms by access standard and assessment type

Clause	Description	PSS®E SMIB	PSCAD SMIB	PSS®E NEM	PowerFactory
S5.2.5.1	Reactive power capability4	Dynamic & Static	Dynamic		Static
S5.2.5.2	Quality of electricity generated				Harmonic model
S5.2.5.3	Response to frequency disturbances	Dynamic			
S5.2.5.4	Response to voltage disturbances	Dynamic	Dynamic		
S5.2.5.5 S5.2.5.5A	Disturbance ride through capability	Dynamic	Dynamic	Dynamic	
S5.2.5.75	Partial load rejection for synchronous production units	Dynamic		Dynamic	
S5.2.5.8	Protection from power system disturbances	Dynamic	Dynamic		
S5.2.5.11	Frequency control	Dynamic	Dynamic		
S5.2.5.12	Impact on network capability			Static Dynamic	
S5.2.5.13	Voltage and reactive power control	Dynamic	Dynamic	Dynamic	
S5.2.5.14	Active power control	Dynamic	Dynamic		
S5.2.5.15	Short circuit ratio		Dynamic		

4 Static studies to be performed with either PSS®E or PowerFactory non-aggregated models

5 Not required for projects applying NER version 234 or later, as S5.2.5.7 was amended to apply only to synchronous production units

Clause	Description	PSS®E SMIB	PSCAD SMIB	PSS®E NEM	PowerFactory
S5.2.8	Fault current				Fault calculation

4.2 Model aggregation

You may use model aggregation to simplify the plant representation, provided you retain the electrical characteristics and control behaviour required for accurate power system studies.

What you need to do

- Use enough aggregated model instances configured appropriately to:
  - represent each transformer interface
  - capture feeder-level electrical and control behaviour
  - distinguish between different technology types
  - support reliable assessment of plant and power system performance.
- Where multiple technologies are connected to the same medium-voltage feeder, use a separate model instance for each technology.

See AEMO's *Power System Model Guidelines* for further guidance on model aggregation.

Modelling the main grid transformer

What you need to do

- Model each main grid transformer separately. Do not aggregate them.
- Include the on-load tap changer (OLTC), where applicable.
- Represent three-winding main grid transformers explicitly as three-winding transformers. Do not aggregate them or convert them to two-winding equivalents.

4.3 PSS®E dynamic model requirements

What you need to do

4.3.1 PSS®E SMIB model

- Submit a PSS®E single machine infinite bus (SMIB) model of the proposed plant that complies with AEMO's *Power System Model Guidelines*, along with a Releasable User Guide (RUG).
- Include PSS®E .sav files representing each corner point of the NER S5.2.5.1 P–Q capability curve under the minimum, typical and maximum short-circuit ratio (SCR) scenarios. See Section 5.2.10 for a description of the PQ capability curves used to assess S5.2.5.1.
- Submit your SMIB model in PSS®E version 34.7 or later.
- Provide a PSS®E version 36-compatible SMIB model to support AEMO's transition to version 36.

- Include benchmarking results demonstrating consistency between the PSS®E version 34.7+ and version 36 models.

See Section 4.3.3 for more advice on the version 36 transition.

4.3.2 Modelling considerations

Bus numbering and dummy buses

- Update the bus numbers in the PSS®E SMIB model to align with the OPDMS numbering provided by AEMO as part of Connection Application submission feedback.
- Do not include dummy buses that do not represent physical buses in the plant or network.
- Where practicable, adopt the OPDMS bus-numbering convention to minimise the changes required after AEMO assigns the relevant station identifier.

See AEMO's OPDMS snapshot guideline in the OPDMS package for further details.

PPC model

If a PPC controls more than one production unit instance in the PSS®E model:

- Do not attach the PPC dynamic model to a specific production unit.
- Represent the PPC as a user-defined bus model attached to the Connection Point bus.

Miscellaneous models

- Try to avoid implementing user-defined models as miscellaneous models.
- If you are considering a miscellaneous model, please consult AEMO for guidance before submission.

Generator reactive power dispatch

- Do not lock the reactive power dispatch in the submitted PSS®E .sav file (i.e., by assigning the same value to the production unit Q_{MAX} and Q_{MIN} limits).
- Set each production unit reactive power dispatch to regulate the Connection Point as the remote bus.
- If the generator instances have different reactive power capabilities, include clear instructions on how the reactive power would be shared between each production unit with the model RUG.
- Use the correct values for RMPCT function of PSS®E with the Connection Point as remote-controlled bus for each generator instance.

4.3.3 PSS®E Version 36 Advice

- Model submissions must support AEMO's PSS®E 36 transition requirements.

What you need to do

- Include in your submission:
  - models in both PSS®E version 34 and version 36
  - the associated dynamic model source code and DLLs for both versions

- benchmarking results between version 34 and version 36.

For further guidance and updates on the transition plan, see AEMO's *PSS®E Version 36 Transition Fact Sheet*.

4.4 PSS®E RUG

Use AEMO's RUG template as the basis for your PSS®E RUG and include all the applicable requirements detailed in this section.

What you need to do

4.4.1 Limits

- Clearly specify all the limits implemented at the plant controller level and at the production units level, including any voltage control components such as:
  - active power/active power command limits
  - reactive power/reactive power command limits
  - any current limits at generator unit level and current priorities
  - voltage limits at the generator unit level, if any

4.4.2 Description of the controls

- Provide an overview of all the controls enabled for the plant, supported by high-level block diagrams of the plant controller and inverter/production unit controllers.

Reactive power control modes

- Provide details of all reactive power control modes, including voltage droop control mode, direct reactive power control mode and power factor control mode (if applicable).
- For each control mode, provide the following information:
- Voltage droop control mode:
  - voltage droop curve, presented graphically, together with the associated settings
  - details of the droop implementation, including the droop base and relevant parameters
  - sufficient information to enable users to modify the voltage droop settings in the model
  - instructions for enabling voltage droop control mode and changing between control modes
  - instructions for changing the voltage setpoint, including the relevant parameter location and units
- Direct reactive power control mode:
  - instructions for enabling direct reactive power control
  - instructions for changing the reactive power setpoint, including the relevant parameter location and units.
- Power factor control mode (if applicable)
  - instructions for enabling power factor control
  - instructions for changing the power factor setpoint, including the applicable power factor sign convention

Active power control modes

- Describe the active power control modes implemented within the plant, supported by high-level block diagrams.
- Provide a detailed description of the frequency droop function and sufficient information to enable users to modify the frequency droop settings in the model, including a:
  - diagram illustrating the frequency droop characteristic
  - complete list of the associated parameters and settings.
- For hybrid facilities where frequency droop functionality is implemented within individual PPCs, include:
  - a schematic representation of the frequency droop function implemented within each PPC
  - the aggregated frequency droop response at the Connection Point
  - the effective total frequency droop at the Connection Point.
- For facilities with multiple DUIDs or PPCs, provide sufficient information to explain the operation of each PPC and the coordination of the individual DUIDs and the plant as a whole.

Reactive current control and limits

- Provide a detailed description of the:
  - reactive current control logic with associated block diagrams, including details of the PPC and inverter/production unit level FRT logic, such as FRT thresholds, hysteresis, K factor, freeze delays, and other relevant settings
  - current limits (i.e., limits on total per phase current, limits on sequence currents, etc.)
  - current-priority logic applied when limits are reached, including positive-sequence Iq, negative-sequence Iq, Id
  - handshaking or coordination logic between the PPC and the inverter/production unit controllers (if applicable).

4.4.3 Operation with reduced number of production units in-service

- Provide instructions for modelling operation with a reduced number of production units in service, including:
  - a complete list of the parameters and settings that require adjustment
  - the methodology for scaling the relevant model parameters
  - instructions for switching harmonic filters, where required below specified levels of production units in service.

4.4.4 Details of temperature derating

- Configure models for the nominal rated temperature of the production units and provide clear instructions for modelling high-temperature derating, including:
  - all production unit-level parameters and settings that require adjustment
  - the methodology for scaling the relevant parameters, including calculation formulas.

- Document all required production unit-level adjustments.
- Do not rely on reducing only the PPC active and reactive power limits to represent equipment thermal derating.

4.4.5 Energy source availability modelling

- Provide clear instructions for modelling energy source availability6, including:
  - reduced solar irradiance
  - night-mode operation
  - operation below the cut-in wind speed.
- Document all model inputs, parameters and control settings required to represent energy source-limited operation.
- Include a diagram illustrating the input energy to output power conversion curve in the RUG. For wind farms, this should include cut-in and cut-out wind speeds.

4.5 PSCAD dynamic model requirements

What you need to do

4.5.1 SMIB model

PSCAD version and compiler compatibility

- Submit a PSCAD SMIB model of the proposed plant that complies with AEMO's *Power System Model Guidelines* together with a model RUG:
  - compatible with PSCAD version 5.0
  - compiled using the Intel® oneAPI Fortran Compiler Classic 2021.x
  - compatible with both 32-bit and 64-bit environments.

Model initialisation

- Initialise the PSCAD case file (.pscx) to the maximum active power and zero reactive power at Connection Point under site-specific minimum SCR (highest network impedance) conditions.
- Provide PSCAD cases for other corner points of the reactive power capability proposed under clause S5.2.5.1.
- Configure the OLTC model of the plant's main transformers to initialise to the correct tap within the first 3 seconds of the simulation run.
- Implement automatic fast tapping of the OLTC during the initialisation period.
- Include any associated instructions on OLTC operation and initialisation in the RUG.

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6 It is highly recommended that OEM advice be sought on the modelling setup, configuration, test methods and any limitations that best represent the plant's performance.

Separate PSCAD model for withstand SCR tests

- Provide the PSCAD model used to perform the withstand SCR tests under S5.2.5.15, if the settings differ from the site-specific PSCAD model. Use the same PSCAD model and DLL as for other GPS clause assessments, changing only the settings necessary for this assessment.
- Clearly identify the parameters that differ from the standard site-specific model and the applicable parameter values.

Inverter representation – detailed switching model vs. average model

- Where the site-specific PSCAD model uses an average representation of power electronic switching devices, provide benchmarking results for the site-specific model, demonstrating close alignment between the average model and the corresponding detailed model with full power electronic switching representation.
- Discuss the scope of studies with Transgrid. The benchmarking must demonstrate close alignment between the models across representative steady-state operating conditions, network strengths and disturbances, including balanced and unbalanced faults, voltage disturbances, control-reference changes and cases that activate relevant control or current limiters.

PSCAD model outputs

- Include all output channels specified in Table 21 of AEMO's *DMAT Guideline*.
- Ensure the sequence components of the inductive and capacitive reactive currents are measured at the Connection Point and the production unit terminals.

Modelling for DC coupled hybrid projects

- For DC-coupled hybrid facilities, ensure the PSCAD model represents the relevant dynamic behaviour of the DC-DC converter with sufficient accuracy for the required assessments.
- Consult Transgrid and AEMO to clarify the expected model representation.

4.5.2 Modelling considerations

Earthing transformers

- Include earthing transformers in the PSCAD model where required to establish an appropriate earth reference and prevent parts of the network, such as delta-connected sections, from floating at an undefined voltage.

Use of dummy resistors

- Do not include large resistors with high impedances (dummy resistors) in the PSCAD models.

4.6 PSCAD RUG

What you need to do

- Prepare the PSCAD RUG in accordance with the AEMO RUG template. As well as addressing the applicable requirements in Section 4.4, the PSCAD RUG must also specify:

- the range of simulation time steps supported by the model
- the compatible Fortran compiler versions
- whether different compiled library files are required for 32-bit and 64-bit environments, together with clear instructions for selecting and linking the correct files for each environment (where applicable).

4.7 PowerFactory model requirements

What you need to do

4.7.1 Harmonic model requirements

- Submit a PowerFactory model in DIgSILENT PowerFactory version 2026 to support the assessment of your plant's harmonic performance at the Connection Point.
- Provide the assessment report as detailed in *Attachment 2 - Harmonic Assessment Requirements*

4.7.2 Protection model requirements

- Submit a PowerFactory model suitable for assessing compliance with NER clause S5.2.8, including accurate modelling of short circuit current contribution of each production unit.
- Ensure the PowerFactory model is consistent with the submitted PSS®E and PSCAD models.
- Provide the completed PowerFactory model checklist in the *Attachment 3 - Submission Checklist* (see *Attachment 4 - Connection Application Folder Structure*).

4.8 Small signal model requirements

What you need to do

- Submit the small signal stability model as early as possible – and definitely before Registration.
- Follow the *Attachment 5 - SSAT model requirement guideline* in the Regional Network Data document.

4.9 SMIB model setup

Many performance assessments for connecting plant are undertaken using a SMIB representation of the power system at the Connection Point. This section outlines how to set up SMIB models for different network conditions and performance assessments.

What you need to do

4.9.1 Modelling the external network

- Model the external network in SMIB using a Thevenin equivalent source. Base the Thevenin series impedance on the specified fault level(s) at the Connection Point.
- If the plant is controlling the voltage at a location other than Connection Point, include all the electrical equipment between the Connection Point and the voltage control point in the SMIB model.

- If the fault levels provided by Transgrid are referenced at the Connection Point and a substation transformer exists between the Connection Point and the voltage control point:
  - model the transformer explicitly
  - consider the transformer impedance when calculating the Thevenin equivalent impedance
  - describe the method used to calculate the Thevenin impedance in the RUG
  - model the transformer OLTC in accordance with the information in the Regional Network Data document.
- Include any Designated Network Asset or Identified User Shared Asset in the SMIB model up to the boundary of the Transgrid network.

4.9.2 Site-specific fault levels and system impedances

- Only consider the fault levels/system impedances in the Supplementary Report when setting up SMIB cases for compliance assessments.
- Do not use site-specific fault levels/system information from the SSPA or from an OPDMS case.

4.9.3 Target voltage

- Tune and test your plant models across the anticipated network voltage range, including onerous operating conditions, to demonstrate compliance with the Generator Performance Standards (GPS)
- Ensure your plant meets its GPS across the normal voltage operating range from 0.9 p.u. to 1.1 p.u. at the Connection Point. Note: system voltage is coordinated by AEMO and/or Transgrid and is adjusted according to the network conditions.
- Use the historical voltage profile from the Supplementary Report to establish representative pre-disturbance voltages and plant voltage setpoints. This data will be provided for the Connection Point where practicable, or for a nearby bus. If the relevant percentile values are unavailable, request them from Transgrid through the RFI process.
- Set up assessment cases using historical voltage data and OLTC operation. As a guide, use:
  - Q_{MIN} : 99th percentile voltage value (V_{HIGH})
  - Q_{ZERO} : 50th percentile voltage value (typical voltage/ V_{NOM})
  - Q_{MAX} : 1st percentile voltage value (V_{LOW})
- Adjust the target voltage reference to achieve different operating conditions (Q_{MAX}, Q_{MIN}, Q_{ZERO}) within the historical voltage range to test the plant in accordance with the droop characteristics and across the reactive power capability range.
- Assess remote voltage control arrangements where applicable (see Section 3.1.1). Additional assessment cases may be required to consider combinations of historical voltages at both the Connection Point and the remote control location. Discuss the scope of any additional assessment cases with Transgrid and AEMO.
- Demonstrate that the generating system has been appropriately tuned across the anticipated operating range. Consult Transgrid and AEMO if you encounter performance limitations or tuning challenges.

The methodology described above is used by Transgrid for selected performance standard assessments, including S5.2.5.5 reactive current injection studies, to assess plant performance under realistic operating conditions.

4.10 OPDMS snapshot selection and study case development

What you need to do

4.10.1 Guide for OPDMS snapshots selection

- Consider a representative range of network conditions when selecting OPDMS snapshots for PSS®E NEM studies.
- Choose cases that demonstrate the connecting plant can:
  - operate stably
  - satisfy the relevant GPS requirements
  - not cause a detrimental impact on existing or committed plant, other network users or otherwise adversely impact network capability.

Note: The number of OPDMS cases required will depend on the size, location and technology of the connecting plant, the proximity of the Connection Point to interconnectors or weaker parts of the network, and the purpose and scope of the assessment. As a guide, consider the OPDMS snapshot selection approach summarised in Table 4-2.

Separate study cases are not necessarily required for each NER clause or assessment. A single appropriately selected and configured study case may be used to address multiple assessment requirements.

See Transgrid's most recent *Transmission Annual Planning Report* for relevant regional loading levels and select OPDMS snapshots that represent the required loading and network conditions. The number of cases identified in Table 4-2 is a guide only. You are responsible for demonstrating compliance under a suitable range of plant dispatch and network conditions. Transgrid and AEMO may request additional studies based on the proposed access standard, observed plant performance and potential network impacts.

Table 4-2 OPDMS snapshot selection approach based on type of assessment

GPS Clause	Assessment scope	Recommended study cases	Matters to be considered
S5.2.5.5 and S5.2.5.5A	• Fault ride-through capability • Stable reactive current injection response • Active power recovery post contingency • Demonstrate that connecting plant does not adversely impact nearby plant	• At least one low demand and low fault level case (set up as per Section 4.10.2) • At least one high demand case with high local area renewable generator dispatch.	• If connecting plant is BESS, nearby BESS should follow a similar dispatch (i.e., charging/discharging) and level consistent with the connecting plant. • Similarly, if the connecting plant is solar or wind, similar energy source availability (therefore similar levels of generation) should be considered for the nearby plants using the same energy source. • Additional sensitivity cases may be required depending on the plant

GPS Clause	Assessment scope	Recommended study cases	Matters to be considered
			size, location and observed performance.
S5.2.5.12	• Demonstrate that connecting the plant does not reduce intra-regional or inter-regional transfer capability. • Demonstrate that the connection does not adversely affect thermal capability, voltage stability or transient stability.	• At least two cases representing high interconnector flows (and/or high intra-regional flows) covering both export and import conditions.	• See the relevant Transgrid Operating Manuals and AEMO's Interconnector Capabilities Report for case tuning. • Additional cases may be required where the connection is close to interconnectors.
S5.2.5.13	• Demonstrate voltage and reactive power control performance (setpoint changes, voltage disturbances, nearby reactive plant switching)	• At least 2 cases: • 1 high fault level case (typically high demand case with high number of synchronous generators) • 1 low fault level case.	• Select cases that provide a representative range of system strength and voltage conditions at the Connection Point. • Additional cases may be required where nearby reactive plant, transformer tap-changing arrangements or other voltage-control interactions are material to the assessment.

4.10.2 Tuning OPDMS snapshots for NEM studies

What you need to do

Network operating information

- Review existing market constraint equations available through AEMO to gain an understanding of relevant regional power system limitations.
- Review the information on network constraints, operating arrangements and transfer limits in the extracts of Transgrid Operating Manuals in the *Attachment 6 - Regional Network Data* document.

Study case development

- Use standard AEMO OPDMS snapshots as the starting point for developing PSS®E NEM study cases.
- Before using the cases for GPS compliance assessments, update them as necessary to:
  - incorporate relevant committed plant
  - represent the latest network configuration
  - adjust the dispatch of nearby plant
  - establish the required demand and fault-level conditions
  - achieve the relevant intra-regional and inter-regional power transfers.

- Consider the demand, fault level, generation dispatch and interconnector flow conditions in Table 4-2.
- Use the general guidance in Table 4-3 to develop high-demand/high-fault-level and low-demand/low-fault-level cases.

Table 4-3 Guidance on study case development

Criteria	High demand/high fault level	Low demand/low fault level
Number of synchronous units	• No specific limit on number of in-service synchronous units • Eraring Power Station units should not be included considering its scheduled retirement	• 2 synchronous units each from the following power stations in NSW (total of 6 units) are typically sufficient for low demand/low fault level case: • Bayswater • Mt Piper • Vales Point
Local area dispatch	• Include all nearby in-service and committed plants, as per the latest plant list provided in Data Pack • High dispatch of nearby plant (for nearby BESS plants discharging/charging consistent with the connecting plant)	• Include all nearby in-service and committed plants, as per the latest plant list provided in Data Pack • High dispatch of nearby plant to the extent where possible (for nearby BESS plants discharging/charging consistent with the connecting plant), subject to achieving the interconnector flow requirement below.
Interconnector flow	• High import into NSW to the extent where possible, while prioritising local area dispatch requirement above.	• High export from NSW

See the latest *AEMO System Strength Report* for information on fault-level requirements at relevant system strength nodes.

- Make sure the study cases represent an appropriate range of operating conditions for the connecting plant, including relevant active and reactive power levels. For a BESS or hybrid facility incorporating a BESS, assess both charging and discharging operation.
- When configuring the dispatch of nearby plant, consider:
  - maximum output from the connecting plant
  - high output from nearby in-service and committed renewable generation
  - for a BESS or hybrid connection, nearby BESS operating in a mode consistent with the connecting plant; for example, charging when the connecting plant is charging and discharging when it is discharging
  - reducing dispatch of the synchronous generators to allow the asynchronous plant to be dispatched at the highest level possible
  - keeping network and interconnector flows within the applicable capability limits specified in the relevant Transgrid Operating Manual extracts and AEMO's *Interconnector Capabilities Report*.
- Review the resulting transmission line flows for the study cases to ensure that:

- all flows are within the relevant system N and N-1 line ratings and satisfy relevant voltage, transient or oscillatory stability constraints
- interconnector flows are as close as possible (but not exceeding) the limits (thermal, voltage, transient and oscillatory stability, as applicable) as specified in OM 520 and the cases are stable.

- In the Connection Study Report (CSR), document for each study case:
  - NSW-VIC, QLD-NSW or NSW-SA interconnector flow levels
  - key transmission line flow levels within NSW
  - all nearby plant considered in the studies and their dispatch levels (MW and as a % of capacity).
- For connections near an intra-regional or inter-regional boundary:
  - consider the relevant in-service and committed generating systems, network conditions and contingencies identified in all Regional Data Documents provided
- For connections near an interconnector:
  - consider relevant plant and dispatch conditions in the neighbouring region.
- Include the OPDMS snapshot cases and dynamic setup files in the Connection Application submission.

Information Specific to Southern Region Connections

- Ensure all study cases represent appropriately stressed network conditions by taking into consideration that:
  - Project Energy Connect (PEC) and HumeLink now have considered status and therefore must be incorporated to the network model. Models and associated RUGs for these two projects are available from AEMO Data Request.
  - Cases must include high power transfers both from VIC to NSW and from NSW to VIC, as applicable. High transfer across Bundey – Buronga 330 kV between NSW and SA to be also considered as applicable.
  - power transfer between NSW and VIC is represented by summated flow on lines Line 65 (Murray – Upper Tumut 330 kV) metered at Murray, Line 66 (Murray – Lower Tumut 330 kV) metered at Murray, Line O60 (Wodonga – Jindera 330 kV) metered at Wodonga, Line X1 and X9 (Red Cliffs – Buronga 220 kV circuits).
  - re-dispatch generation in North-West VIC and South-West NSW is needed to achieve a high-power transfer on Lines X1 and X9.
  - re-dispatch generation in Victoria and Central-West NSW is needed to achieve a high level of transfer on the Eastern 330 kV corridor (Lines 65, 66, O60).
  - the interconnector flows should be close to (but not exceeding) the applicable limits for NSW-VIC and NSW-SNOWY specified in OM 520 (PEC limits are specified in PEC limit advice included in your Regional Data Pack)
  - voltage stability limits for Line 63 between Darlington Point and Wagga Wagga and Line 51 between Wagga Wagga and Lower Tumut must not be exceeded

Information Specific to Northern Region Connections

- Ensure all study cases represent appropriately stressed network conditions by taking into consideration that:
  - the high- and low-demand cases must include high power transfers both from QLD to NSW and from NSW to QLD.
  - re-dispatch generation in Southern Queensland and Northern NSW and Central-Coast NSW is required to achieve high level of transfer across QNI. See OM 520 and AEMO's *Interconnector Capabilities Report* for the applicable QNI limits.
- Information Specific to Central Region Connections
- Ensure all study cases represent appropriately stressed network conditions by taking into consideration that:
  - The high- and low-demand cases must include, depending on the connecting location, either
- high power transfers both from QLD to NSW and from NSW to QLD or
- high power transfers both for NSW to VIC and VIC to NSW
- See OM 520 and AEMO's *Interconnector Capabilities Report* for the applicable interconnector limits.

4.10.3 Robustness of NEM base cases

- Run each base case without a disturbance (i.e., flat-run) for at least 40 seconds to ensure that a steady state solution is reached.
- Verify steady state operation by monitoring the bus voltages, line flows, and synchronous machine rotor angles.
- Investigate and resolve any material drift, sustained oscillation or unexpected control response observed during the flat run before using the case for assessments.

4.10.4 Presenting the results for OPDMS studies

- Plot the following signals, at a minimum, when presenting OPDMS results. Curves and legends must clearly distinguish:
- Voltage, P and Q flows and frequency at the CP and production unit level of the plant under study.
- Voltage, P and Q flows of nearby plants and Synchronous Condensers
- P and Q flows of the nearby transmission lines
- Voltage of nearby buses
- Relative rotor angles of large synchronous generators in the region
- Interconnector P and Q flows in the region
- Voltage magnitude, angle and frequency of either side of interconnector substations

Chapter 5

Assessment requirements by Access Standard

This section outlines the minimum recommended scope of the technical studies you must undertake to assess proposed performance standards and demonstrate compliance.

Note: this is not an exhaustive scope. Transgrid may request additional studies, sensitivities or assessments during the due diligence process.

5.1 Operating scenarios

Your plant assessment must cover a representative range of operating scenarios across the full operating capability of the proposed facility. The sections below describe the minimum sets of operating scenarios for each technology arrangement.

What you need to do

- Provide the SMIB test cases with the relevant operating scenarios setup in both PSS®E and PSCAD.

5.1.1 Active Power Dispatch Scenarios

- Assess active power dispatch scenarios as set out in Table 5-1 to Table 5-4 where:
  - $P_{100\%}$ - maximum active power export at the Connection Point
  - P_{min} - minimum active power export at the Connection Point
  - $P_{-100\%}$ - maximum active power import at the Connection Point

Generating systems

Table 5-1 Generating systems - active power operating scenarios

Scenario	Connection Point active power	
1	$P_{100\%}$	Maximum active power output
2	P_{min}	Minimum active power output

Battery energy storage systems

Table 5-2 BESS - active power operating scenarios

Scenario	Connection Point active power	
1	$P_{100\%}$	Maximum P exporting (discharging) of BESS
2	$P_{0\%}$	P = 0 of BESS, only providing Q support
3	$P_{-100\%}$	Maximum P importing (charging) of BESS

Note: These same scenarios are also for DC-coupled hybrid connections if the DC side resources are **not** independently dispatched.

Hybrid integrated resource systems

- Assess AC coupled hybrid systems against the scenarios in Table 5-3 (full scope of studies) and Table 5-4 (limited set of studies).

Table 5-3 Hybrid active power operating scenarios to be considered for a **full scope of studies**

Scenario	CP Active power	PV/Wind - availability	BESS-availability
Hybrid operation			
1	$P_{100\%}$	Maximum $P_{PV/wind}$ output from PV/wind	P_{BESS} = ($P_{100\%}$-$P_{PV/wind}$) from BESS
2	$P_{0\%}$ (Internal charging)	High $P_{PV/wind}$ (>0.9 p.u.) output of PV/wind. If there are any internal charging limits, use the limit to be the PV/wind generation	High P_{BESS} input (>0.9 p.u.) at machine level (charging) of BESS. If reaching BESS capability, use BESS capability.
BESS only operation			
1	$P_{100\%}$	Disconnected (No P&Q support)	Maximum P exporting (discharging) from BESS
2	$P_{-100\%}$	Disconnected (No P&Q support)	Maximum P importing (charging) from BESS
PV/Wind only (if PV/Wind only is a valid operating scenario)			
1	$P_{100\%}$	Maximum P output from PV/wind	Disconnected (No P&Q Support)
2	P_{min}	Minimum P output from PV/wind	Disconnected (No P&Q Support)

Table 5-4 Hybrid active power operating scenarios to be considered for a **reduced scope of studies**

Scenario	CP Active power	PV/wind - availability	BESS-availability	Recommended minimum scope of NER Assessments
Hybrid operation				
3	$P_{100\%}$	$P_{PV/wind}$ = ($P_{100\%}$-P_{BESS}) from PV/wind, subject to: $P_{PV/wind}$ > minimum active power level of the PV or wind	Maximum P_{BESS} exporting (discharging) from BESS	S5.2.5.4, S5.2.5.5. S5.2.5.11
47	P_{High}	$P_{PV/wind}$ = 0 MW, only provide Q support, Q-at-night	Maximum P_{BESS} exporting (discharging) from BESS	S5.2.5.4, S5.2.5.5, S5.2.5.13

Note: These same scenarios are also for DC-coupled hybrid connections if the DC side resources are independently dispatched.

7 only if Q-at-night operation model is proposed.

5.1.2 SCR and Reactive Power Dispatch Scenarios

- Consider the SCR requirements and reactive power levels in Table 5-5 for each performance standard assessment.

Table 5-5 Summary of SCR and Connection Point reactive power scenarios for each access standard

Clause	Description	SCR (min)	SCR (typical)	Infinite Grid	Q_{MAX} (V_{LOW})	Q_{ZERO} ($V_{NOMINAL}$)	Q_{MIN} (V_{HIGH})
S5.2.5.1	Reactive power capability			Y			
S5.2.5.3	Frequency disturbances	Y			Y		Y
S5.2.5.4	Voltage disturbances			Y	Y	Y	Y
S5.2.5.5 S5.2.5.5A	Fault response	Y	Y		Y	Y	Y
S5.2.5.8	Protection from power system disturbances	Y					
S5.2.5.11	Frequency control	Y			Y		Y
S5.2.5.13	Voltage control	Y	Y		See section 5.15	See section 5.15	See section 5.15
S5.2.5.14	Active power control	Y			Y	Y	Y

5.1.3 Multiple generating system assessment scenarios

Where a Connection Application includes multiple generating systems connected at the same Connection Point or to a common bus, avoid unnecessary duplication by undertaking some GPS compliance studies on a combined-plant basis. Transgrid's Guide on *GPS Assessment Guide for Multi-Generating System Applications* specifies the site-specific model configurations and studies that may be assessed collectively and those that require separate assessment of each generating system.

What you need to do

Take into account that:

- The applicable GPS clause may require assessment with multiple generating systems in service, with each generating system operating individually, or under both scenarios.
- Studies must use the site-specific fault levels and system impedances specified by Transgrid. The fault level at the Connection Point does not change because one or more generating systems are offline.
- Project circumstances may vary. Engage with Transgrid early and provide a clear development plan covering the proposed staging, programme and technical configuration to identify opportunities to minimise duplication and rework.

5.1.4 Q-at-night mode/ operation below cut-in wind speed

- Undertake a reduced assessment scope covering, at a minimum, the assessment requirements specified in Section 5.19.

Note: this applies to PV plants operating in Q-at-night mode and wind farms operating below the cut-in wind speed, including hybrid facilities.

5.2 Reactive power capability – S5.2.5.1

NER Clause S5.2.5.1 requires the plant to have sufficient reactive power capability to support voltage control at its Connection Point. This is necessary to maintain voltage within acceptable limits under the range of expected operating conditions.

What you need to do

- Demonstrate the plant's ability to both supply and absorb reactive power at the Connection Point in accordance with the agreed performance standard.

5.2.1 Expectations and acceptance criteria

- Assess the plant's reactive power capability across the full active power operating range and for Connection Point voltages within ±10% of nominal voltage.
- Test all valid plant operating modes, including all valid dispatch configurations the unconstrained and constrained scenarios defined in Table 5-6.
- Account for temperature derating. If the plant capability derates as temperature increases:
  - provide separate Connection Point reactive power capability curves for different temperatures up to maximum operating temperature (e.g. maximum non-derated temperature and maximum operating temperature) to establish applicable derating at the CP.
  - document the temperature derating characteristics of the production units in the CSR and the RUGs.
- Demonstrate that your proposed S5.2.5.1 reactive power capability is compliant with the S5.2.5.4 CUO requirements across the operating scenarios and temperatures.

Table 5-6 Unconstrained and constrained S5.2.5.1 capability

Unconstrained capability	Constrained capability
• Derived using steady state studies in PSS®E or PowerFactory • Based on plant raw capability • Plant controller limits are removed • Transformer OLTC operation is allowed	• Derived based on dynamic studies in PSCAD or PSS®E • Plant controller operation included with all applicable limits • Transformer OLTC operation is considered

- Present the plant's reactive power capability as a P–Q capability chart showing the maximum reactive power absorption and injection across the plant's active power range. The P–Q capability chart must:

be provided in switching a ficticious capacitor/reactor

  - format using the template included in *Attachment 4 - Transgrid folder structure*
  - show the plant capability and applicable Automatic Access Standard (AAS) based on the project's maximum capacity
  - follow the format of the relevant example in Figure 5-1 or Figure 5-2, depending on the relevant NER version, including the legend
  - clearly number all corner points using a legible font.

- Include the proposed P–Q capability of the plant for voltage levels within ±10% of the nominal voltage.
- If the capability is different beyond ±5% of the mid-point voltage nominated by Transgrid, provide separate P–Q capability curves as per Figure 5-2 to cover:

  - Connection Point voltage within ±5% of mid-point voltage
  - Connection Point voltage between 90% of nominal voltage and 5% of mid-point voltage
  - Connection Point voltage between 5% of mid-point voltage and 110% of nominal voltage

The mid-point voltage is specified in Transgrid's Network Planning Supplementary Report.

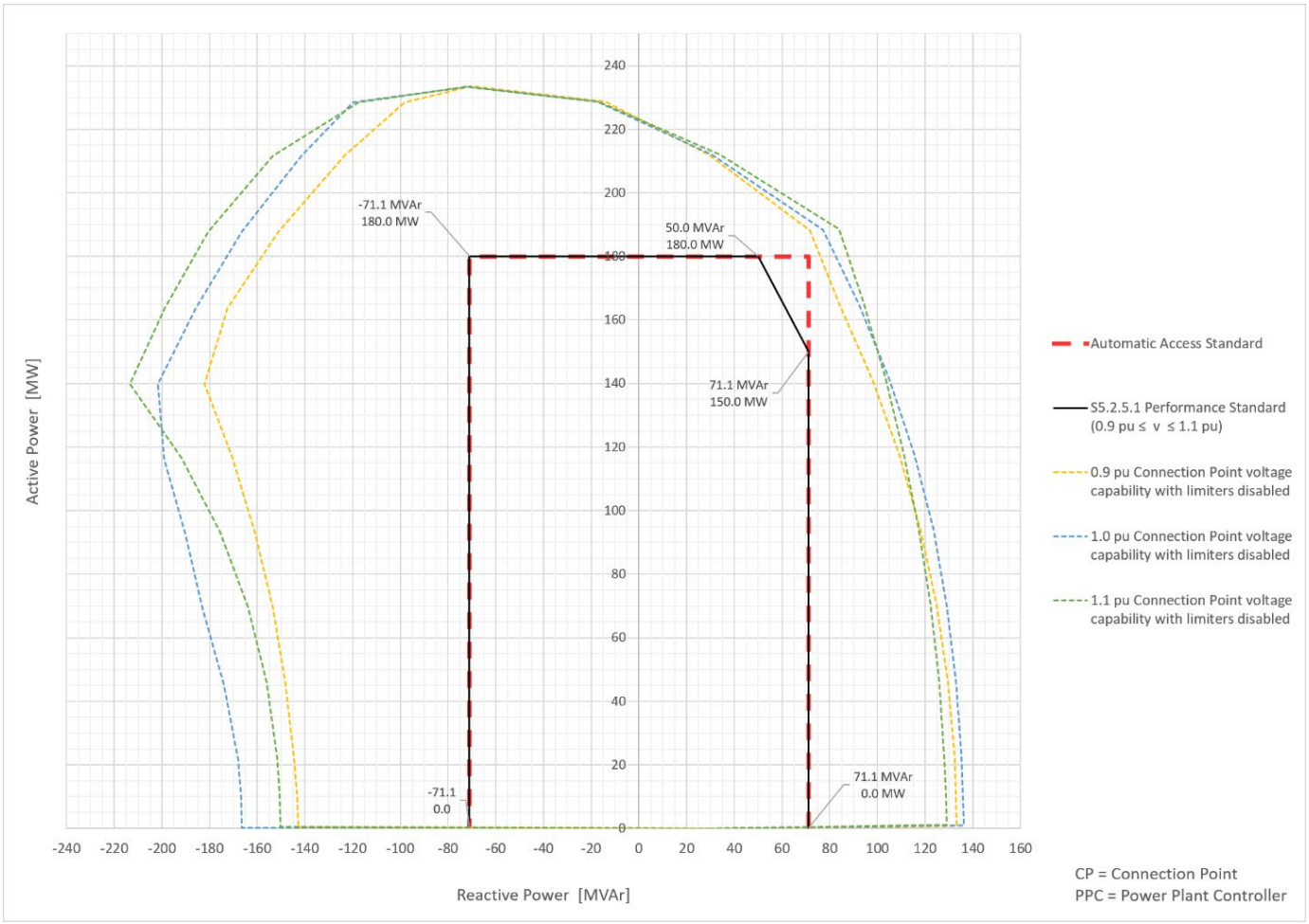


Figure 5-1 Example of a P-Q capability curve format for a 180 MW uni-directional plant with a negotiated performance standard

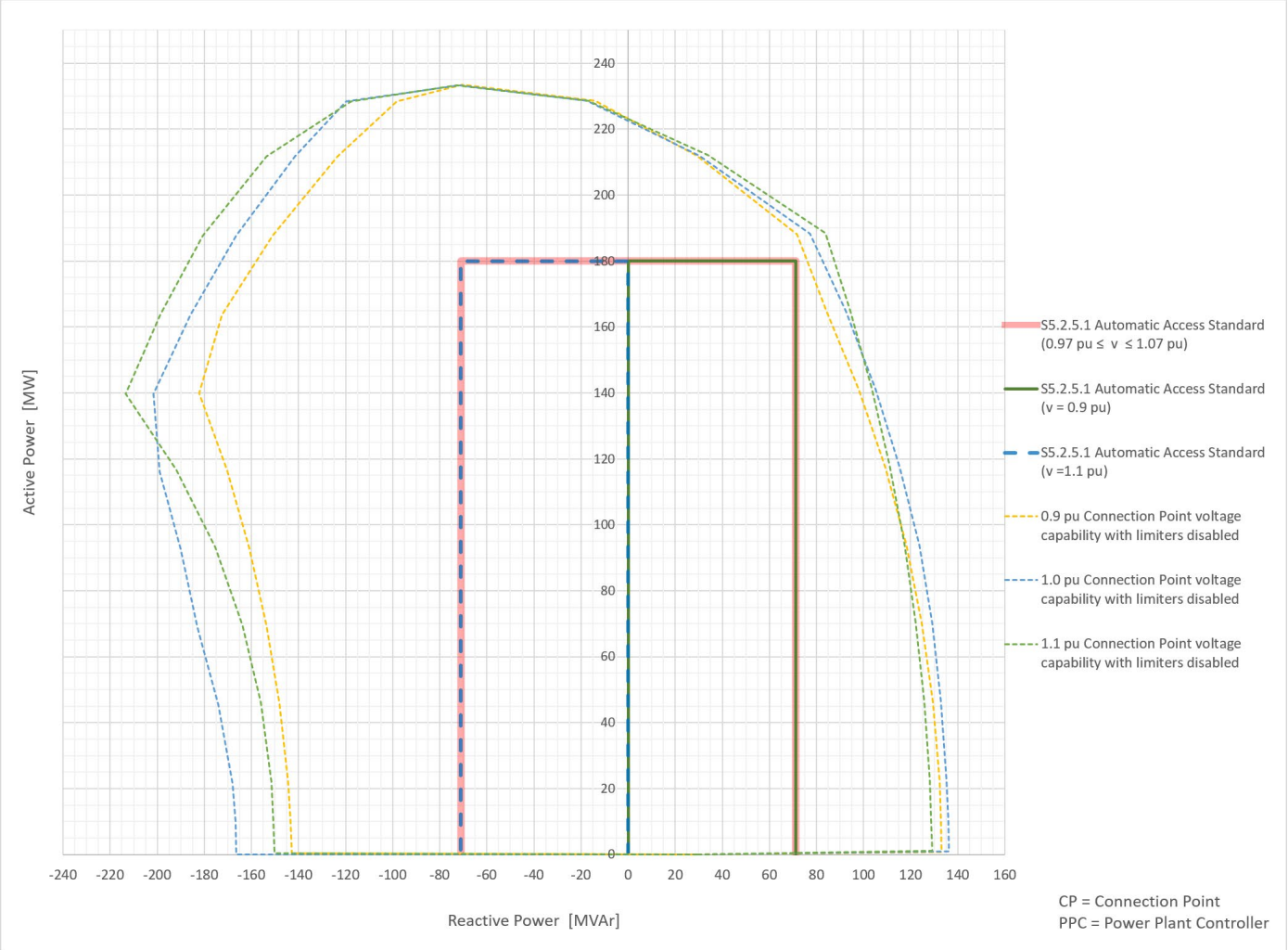


Figure 5-2 Example of a P-Q capability curve format for a 180 MW uni-directional plant with a mid-point voltage of 1.02pu

Note: The example assumes a midpoint voltage of 1.02 p.u. and illustrates the AAS applicable under NER version 234 or later. Include the proposed performance in addition to the curves shown.

The proposed performance standard for S5.2.5.1 in the GPS must include:

- The proposed reactive power capability at the normal operating temperature
- The proposed capability at higher temperatures, including the applicable derating methodology
- The maximum operating temperature and the operational arrangements that apply above this temperature
- Any reactive power compensation required when the plant is not generating.

You do not need to include the unconstrained PQ capability curves in the proposed GPS. However, the VCS and the RUGs require the full capability charts, including unconstrainted capability (see Figure 5-1 or Figure 5-2). See the VCS guide for more details.

5.2.2 Methodology

Unconstrained capability

- Assess the unconstrained reactive power capability of the plant using either PSS®E (aggregated model) or PowerFactory(detailed model without aggregation) steady state load flow analysis.
- When modelling the plant in detail without aggregation, wind plants must use PowerFactory.
- Determine the maximum reactive power capability at the Connection Point for each specified Connection Point voltage. Base the assessment on the maximum capability of the production units, without applying PPC limits. OLTC operation may be considered.
- Check the following equipment limits are met when determining the maximum reactive power capability:
  - MV and HV bus voltages remain within the normal operating range of 0.9 p.u. to 1.1 p.u.
  - Transformers are not thermally overloaded
  - Production unit terminal voltages remain outside the FRT and protection activation ranges
  - Production unit-level current and power limits are observed.
- Document all limits and assumptions used to determine reactive power capability in the CSR.

Constrained capability

- Determine the constrained reactive power capability of the plant using PSS®E or PSCAD dynamic studies with an infinite bus SMIB configuration, based on all plant components and associated limiters in-service.
- Where the main transformer is equipped with an OLTC, represent the OLTC using a dynamic model. To reduce the overall simulation time, use a sufficiently shorter OLTC time constant.
- Perform the dynamic simulations as follows:

Operate the PPC in voltage droop control mode8.

Using the infinite bus voltage source, ramp up the Connection Point voltage to the desired voltage (0.9 p.u.,1.0 p.u, 1.1 p.u., and ±5% of mid-point voltage).

Wait for the PPC to achieve the desired active power level – or set up the load-flow solution with the active power output at the desired level.9

Apply to the PPC a voltage setpoint sufficiently large enough to force the reactive power flow at the Connection Point into the capability limits.

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8 Note that some models apply setpoint limits at the PPC level which could prohibit the true capability of the plant being achieved. In this case, switch the plant to reactive power control mode instead and note it in the report.

9 Some PPCs have relatively slow active power ramp rates, so this can help reduce the simulation time required to achieve the desired active power level.

Once steady state has been reached in the simulation, take RMS measurements of P\Q\V at the Connection Point and production unit terminals.

Repeat Steps 1 to 5 for a range of active power levels (e.g., -100%,10 -50%, 0%, 50% and 100%) to create a P–Q chart.

If a Negotiated Access Standard is proposed, consider all the corner points of the P–Q curve.

10 Or minimum possible power output.

Common issues, considerations and recommendations

Reactive power compensation when not generating active power

When the plant is electrically connected to the network without generating active power, it must limit the resulting voltage change at the Connection Point. Relevant operating conditions include:

- Night-time operation of solar farms
- Operation of wind farms below cut-in wind speed
- Operation of battery storage systems at minimum state of charge
- Operation of the plant when production units are disconnected

Under these conditions, the balance of plant equipment such as collector network, transformers, capacitor banks, harmonic filters, etc., will supply or absorb reactive power and affect the voltage at the Connection Point.

The applicable Access Standards for the allowable change in the voltage at the Connection Point are:

- AAS (NER S5.2.5.1(a2)) – requires the voltage to not change when the plant connects
- MAS (NER S5.2.5.1(b2) – requires the magnitude of the voltage change to be less than 1% when the plant connects.

Note: NER S5.2.5.1 requires that the magnitude of the voltage change at the Connection Point to be calculated using steady state conditions and for the highest system impedance nominated under clause S5.2.5.13(m). The assessment should also consider an initial Connection Point voltage of 1.1 p.u. to account for the maximum reactive power associated with collector cables and harmonic filters.

The requirements under S5.2.5.1 (a2) and (b2) can be met by:

- Using the reactive power capability from the production units. Where this approach is proposed, indicate in the GPS how many production units would be required to provide the necessary reactive power compensation and the plant operation under S5.2.5.13.
- Operational arrangements to disconnect balance of plant equipment such as switching out collector network and/or the harmonic filters when the production units are not connected.
- Installing additional reactive compensation equipment to offset balance of plant reactive power.

As part of your Connection Application, you must propose and describe how the plant will meet this requirement for Transgrid's assessment.

Common issues, considerations and recommendations

Operational capability at higher temperatures

For compliance with NER version 234 or higher, the GPS should clearly specify the active power capability, the maximum temperature for operation and expected plant operation beyond that temperature (for example, linear reduction of power at the production unit terminals to zero above the maximum operating temperature). Where applicable, the GPS must specify the temperature-derating relationship for ambient temperatures below the maximum operating temperature, including whether the capability is derated linearly or in accordance with another defined function, curve or methodology.

Where the plant cannot meet the AAS reactive power capability of 39.5% of maximum active power at higher temperatures, the proposed negotiated reactive power capability should aim to provide at least 39.5% of the linearly derated active power.

5.3 Quality of electricity generated – S5.2.5.2

5.3.1 Expectations and acceptance criteria

NER clause S5.2.5.2 is intended to ensure that the connecting plant does not cause power quality levels to exceed the applicable standards. This includes voltage fluctuations (flicker), harmonic voltage distortion and voltage unbalance.

What you need to do

- Undertake the harmonic assessment in accordance with Transgrid's *Attachment 2 - Harmonic Assessment Requirements* in the Data Response.
- Design the plant to meet the project-specific AAS power quality emission limits specified in the CPTSR.
- Where necessary, incorporate appropriate harmonic filters into the plant design to achieve the allocated AAS harmonic emission limits.
- If you cannot meet the AAS for one or more harmonic orders and propose a Negotiated Access Standard, consult Transgrid with appropriate assessment evidence and justification.
- Repeat the harmonic assessment as part of the R1 capability assessment using the final plant design. This assessment must incorporate the final balance-of-plant configuration, reticulation system, transformer impedances, harmonic filters and any other equipment or design parameters that may materially affect harmonic performance.

5.4 Response to frequency disturbances – S5.2.5.3

5.4.1 Expectations and acceptance criteria

NER clause S5.2.5.3 requires the plant to remain in continuous uninterrupted operation for a range of frequency disturbances. After a disturbance is cleared and the frequency is returned to pre-disturbance level, the plant response must also return to the pre-disturbance level.

What you need to do

- Provide a frequency vs protection time threshold graph comparing the production unit frequency ride-through capability against the applicable NER AAS requirement.

5.4.2 Methodology

- Assess the plant's frequency ride-through capability using a PSS®E dynamic model.
- Conduct tests at the minimum fault level for the combinations of operating scenarios listed in Section 5.1.1
- Provide plant response for the frequency disturbances listed in Table 5-7. The disturbances can be simulated in a sequence or individually. In each case, the frequency must return to 50 Hz after the disturbance. Consider the following rate of change of frequencies (RoCoF) when applying the frequency disturbances:
  - ±4 Hz/s for the first 0.25 s
  - ±3 Hz/s for the remaining duration

Table 5-7 Frequency disturbance ride-through tests

Disturbance	Frequency [Hz]	Duration [s]
1	52	120
2	51	600
3	49	600
4	47	120

Common issues, considerations and recommendations

Unstable frequency response under very low SCR scenarios

Unstable plant responses may in some cases be observed in SMIB studies for extreme frequency disturbances such as 52 Hz and 47 Hz. Where this occurs, investigate available plant tuning options to improve this behaviour. However, where the instability is due to power transfer limitations at low SCR in a SMIB environment, you may provide supporting evidence to confirm this limitation in the CSR (e.g. by including PV or QV curve analysis under site-specific conditions). However, do not compromise other aspects of plant performance to solely address this behaviour.

Where significant instability occurs under less extreme frequency disturbances, try using parameter tuning to improve the plant response. If further tuning is not feasible, discuss alternative solutions with Transgrid and AEMO. Generally, limiting the maximum active power change (dP) for a frequency response is not the preferred approach. If this is the only viable option, provide evidence and seek formal approval from Transgrid and AEMO.

At low fault levels, during large active power changes, the plant may enter FRT mode during a frequency disturbance. This behaviour may be more pronounced in SMIB studies, which do not incorporate voltage support from nearby dynamic plant present in the network. In such cases, consider undertaking further assessment using a wider network representation (for example, using the PSS®E NEM Model) to demonstrate whether the observed behaviour is specific to the SMIB representation.

5.5 Response to voltage disturbances – S5.2.5.4

5.5.1 Expectations and acceptance criteria

NER clause S5.2.5.4 requires the plant to remain in continuous uninterrupted operation during a range of voltage disturbances, without disconnecting or becoming unstable.

What you need to do

- Demonstrate ride-through capability for specified under-voltage and over-voltage events using both the PSS®E and PSCAD dynamic models.
- For longer-duration voltage disturbances, including the 1.15 p.u. over-voltage disturbance, demonstrate:
  - the exact duration using the PSS®E dynamic model
  - at least 20 seconds using the PSCAD dynamic model.
- Demonstrate that, after the disturbance is cleared and the Connection Point voltage returns to the pre-disturbance level, plant response also returns to the pre-disturbance level. The response should demonstrate that no unintended limiters remain active and that the plant does not remain latched in fault ride-through mode.

- Complete a production unit CUO capability assessment in PSCAD to demonstrate that the plant is appropriately sized to maintain both the active and reactive power at the Connection Point for voltage variations of up to ±10% within the normal operating voltage range.
- If production units are derated within the proposed operating temperature range, conduct the production unit CUO capability assessment at both the normal operating temperature and the proposed maximum operating temperature.
- Where the Voltage Control Point of the plant is not at the Connection Point, demonstrate the ride through capability at the Connection Point.

5.5.2 Methodology

- Use the historical voltage range in the Network Planning Supplementary Report for the S5.2.5.4 assessments.

5.5.2.1 Voltage ride-through assessment

- Use a SMIB model with an infinite source to represent the network.
- Assess the voltage and duration of the voltage disturbances in Table 5-8, using the applicable operating scenarios in Section 5.1.
- For hybrid integrated resource systems, the operating scenarios in Table 5-3 must be assessed as a minimum. These represent the more onerous or boundary operating conditions.
  - Include, as a minimum, the tests in Table 5-8, conducted either:
    - Individually for each voltage level for the required duration (preferred approach). In this case, return the Connection Point voltage to the pre-disturbance level after the specified duration or
    - As a continuous voltage profile containing multiple steps for each voltage level for the required duration. In this case, return the Connection Point voltage to the pre-disturbance level after all the steps in the voltage profile is completed.
    - Perform the voltage profile tests with unbalanced voltages (only one or two phases reaches the expected voltage levels given in Table 5-8 while the healthy phase/s remains at pre-disturbance level). Plot individual phase voltages at the Connection Point for these tests.
- For all simulations:
  - Lock the transformer taps11.
  - Create the disturbances using the standard library PLBVFU1 model or AEMO's ZINGEN model in PSS®E.

Table 5-8: Voltage disturbances for S5.2.5.4

11 OLTC operation can be considered for disturbances longer than the OLTC delay time, if required.

Connection Point voltage [p.u.]	Disturbance duration12 [s] (from the start of the disturbance)
>1.3	0.02
1.3	0.2
1.25	2
1.2	20
1.15	1200
1.1	1200
0.9	1200
0.8	10
0.7	2

Your CSR must include:

- An assessment of the plant's ride-through capability
- Plots showing the PPC active and reactive power commands issued to the production units, together with the FRT flags and other relevant control signals.

5.5.2.2 Production unit CUO capability assessment

Use this assessment to confirm that the total installed capacity of the production units is sufficient to deliver the required active and reactive power at the Connection Point while maintaining CUO across the normal operating voltage range.

What you need to do

- Perform the CUO assessments for the following scenarios in primary voltage control mode, initialising the cases to the operating scenarios in Section 5.1:
  - Initial Connection Point voltage set at 1.0 p.u.
    - Apply voltage disturbance to 0.9 p.u. and 1.1 p.u.
    - Maintain each disturbance for 20 seconds.
  - Initial Connection Point voltage set at historical voltage

12 The disturbance duration for each voltage step is measured from the commencement of the disturbance.

- Apply Voltage disturbance of ±0.1 p.u. while ensuring that Connection Point voltage remains within 0.9 p.u. to 1.1 p.u.13
- Maintain each disturbance for 20 seconds.

- Measure the values of P/Q/V at the Connection Point and terminals once the plant has reached steady state operation during the disturbance (for example, at 15 s).

Common issues, considerations and recommendations

Considering the operation of OLTC

For voltage variations of **10% or less** within 90-110% of nominal voltage:

- Maintain CUO without sole reliance on OLTC operation.
- Use a co-ordinated strategy using production units' short-term overload capability, plant switching and OLTC operation to meet the CUO requirement at the Connection Point.
- Provide sufficient OEM documentation to demonstrate the applicable short-term overload capability.

Only rely on the OLTC when assessing the plant's voltage ride-through capability where the disturbance duration exceeds the OLTC operating time delay. Tap-changing actions can take minutes to respond. If plant relies solely on a tap-changing transformer to respond to a voltage disturbance, without any other voltage control measures, it will not meet the CUO requirements because active power and reactive power output will reduce until the tap change is completed.

For voltage disturbances within 90-110% of nominal voltage, where the voltage variation is **greater than 10%**, you can correct active power reduction at the Connection Point by OLTC operation, as long as the disturbance duration exceeds the OLTC operating time delay.

FRT re-triggering

Transgrid expects the fault ride-through (FRT) to activate during a sufficiently high over-voltage or low under-voltage disturbance. However, consider tuning the FRT if it retriggers as the voltage returns to the normal range (0.9 p.u. – 1.1 p.u.) following the disturbance. When voltage returns to the normal operating range, the plant's active power should return to its pre-disturbance value, or to a value consistent with the control requirements under NER clause S5.2.5.13.

Plant at Connection Point voltage of less than 66 kV

If the plant is connecting to a MV network where the Connection Point voltage is less than 66 kV with no automatic tap changing transformer, the location of the S5.2.5.4 compliance assessment can be negotiated to the nearest location at or above 66 kV as agreed with AEMO and Transgrid.

13 For example, from V_{High} to the minimum of 1.1 p.u., and V_{High}+0.1 p.u.

5.6 Disturbance ride-through capability – S5.2.5.5

5.6.1 Expectations and acceptance criteria

NER Clause S5.2.5.5 requires the plant to remain in continuous uninterrupted operation during and following specified power system disturbances. This includes demonstrating the plant's ability to ride through credible contingency events and multiple disturbances without disconnection.

What you need to do

- Undertake a range of SMIB and wide-area NEM studies, using the SMIB scope indicated in Section 5.1, to demonstrate that the connecting plant:
  - remains in CUO during and following the disturbances specified in NER clause S5.2.5.5
  - maintains stable and adequately controlled operation throughout each disturbance and the subsequent recovery period.
- Provide studies that demonstrate effective coordination between the PPC and production unit controls, including that the:
  - PPC and production units enter FRT mode in a coordinated manner for disturbances that exceed the applicable LVRT or HVRT initiation thresholds
  - PPC does not exhibit control windup when the production units are in FRT mode but the PPC is not
  - production unit controls do not exhibit control windup when the PPC is in FRT mode but the production units are not.

Note: The appropriate coordination arrangement will depend on the OEM's control design. However, to prevent control windup, conflicting control responses or poorly controlled plant behaviour, coordinate the FRT thresholds, hysteresis, delays and associated control settings of the PPC and production units. Provide sufficient studies to demonstrate this coordination across the applicable disturbance range.

5.6.2 Methodology

5.6.2.1 Scope of the PSS®E NEM studies – credible contingencies

See Section 4.10 for how to set up the base cases for the PSS®E NEM studies.

- Consider contingencies involving a representative range of network elements near the proposed connection, including:
  - Transmission lines and transformers
  - Shunt reactive plant
  - Large loads
  - Large synchronous generating units, including relevant units in other regions, such as Loy Yang or Kogan Creek.

- For projects located near the NSW border, include relevant contingencies in the adjoining region, such as Victoria or Queensland.
- Assess a range of fault types, including balanced and unbalanced faults and contingencies involving automatic reclosing. Use primary and circuit-breaker-fail protection clearance times in accordance with the NER requirements.

Note: The applicable network elements and protection clearance times are specified in the relevant Regional Network Data Documents. For contingencies in other NEM regions, use the standard NER protection clearance times in Table S5.1a.2 unless otherwise directed by Transgrid or AEMO. Where applicable, incorporate relevant special protection schemes in the Data Response.

5.6.2.2 Multiple fault ride through (MFRT) requirements

- Complete the multiple contingency assessments required by AEMO in the DMAT. Transgrid does not expect additional extensive assessment of multiple contingencies.
- Provide a written report or letter from the OEM to confirm the capability of the plant to ride through multiple contingencies, as required in S5.2.5.5. The OEM must provide evidence such as a PSCAD study or a FAT report to justify its ability to comply. This evidence should include:
  - The minimum SCR at the production unit terminals that the units can remain connected and perform as close as is reasonably practicable to CUO. Transgrid expects that the units will remain in stable operation but does not require strict CUO compliance.
  - Details of any plant limitations that impede the plant's ability to remain in CUO, such as fault counters that trip the plant, temperature thresholds in the chopper circuit, total cumulative current in a certain time interval. These plant limitations must not reduce plant's capability to meet the proposed access standard for MFRT.
  - Confirmation that these plant limitations are captured in the OEM's PSS®E and PSCAD models.
- Include the minimum SCR at the production unit terminals and the OEM-identified plant limitations in your proposed GPS.

Note: the selection of plant settings and tuning must not prohibit the MFRT capability of the plant. This includes coordinating relevant PPC and production unit settings, such as FRT mode exit delays.

5.6.2.3 Scope of the PSCAD SMIB studies – single balanced and unbalanced faults

Assess the plant's response to balanced and unbalanced faults using the PSCAD SMIB model for the operating scenarios specified in Section 5.1.

Table 5-9 Fault response operating scenarios

Parameter	Values
Connection Point Voltage	V_{HIGH} for Q_{MIN}, V_{NOM} for Q_{ZERO} V_{LOW} for Q_{MAX}
Connection Point active power	• Operating scenarios as per Section 5.1
Connection Point reactive power	Q_{MAX}, Q_{ZERO}, Q_{MIN}
Fault level	Minimum and typical

- Apply faults at the Connection Point using the following methodology:
  - adjust the fault impedance to achieve a range of Connection Point voltage depths (maintain the fault X/R ratio at the same value as the Thevenin impedance)
  - assess a representative range of fault types, including three-phase-to-ground (3PHG), two-phase-to-ground (2PHG), single-phase-to-ground (1PHG) and phase-to-phase faults
  - assess retained voltage over the ranges of 0.0-0.7 pu and 1.25-1.35 pu, using increments of no more than 0.1 pu.
  - for shallow disturbances with retained fault voltages between 0.7-0.9 pu and between 1.1-1.25 pu, the voltage increment between disturbances should be reduced (e.g. to 0.02 pu) to provide additional data points around the commencement threshold.
- Apply the longer of:
  - the applicable fault clearance time specified in NER clause S5.1a.8, corresponding to column 4 of Table S5.1a.2
  - at transmission voltage levels:
    - for unbalanced faults, the longest specific circuit-breaker-fail protection clearance time in the nearby network
    - for 3PHG faults, the longest specific primary protection clearance time in the nearby network.

See the Regional Data document for specific clearance times.

5.6.2.4 Scope of the PSS®E SMIB studies – single balanced faults

- To ensure performance of the PSS®E model is consistent with the proposed performance standards, carry out fault tests in PSS®E following a similar approach to that specified for PSCAD.
- Conduct tests according to the operating scenarios listed in Table 5-10.

Table 5-10 Fault response operating scenarios

Parameter	Values
Connection Point Voltage	V_{HIGH} for Q_{MIN}, V_{LOW} for Q_{MAX}
Connection Point active power	Operating scenarios as per Section 5.1
Connection Point reactive power	Q_{MAX}, Q_{MIN}
Fault level	Minimum

Note: pending the performance of the PSS®E model, Transgrid and AEMO may request additional studies. The subset of PSS®E testing can only be reduced if sufficient studies are provided in DMAT, benchmarking and NEM studies.

Common issues, considerations and recommendations

Unstable responses in NEM studies

Where the plant and/or network response is unstable following a tested contingency, replace the plant model with an equivalent negative load and repeat the study. This comparison should be used to determine whether the instability is caused by the plant's dynamic response or is pre-existing under the modelled network conditions.

Where the instability is pre-existing, investigate its cause and confirm that the network initial conditions are appropriate, including:

- No excessive thermal overloading under N-1 conditions
- Appropriate network voltage profiles
- Interconnector flows within the applicable stability limits.

Where the network has been configured under excessively onerous conditions (for example, with QNI flow above the applicable transient stability limit) the base case should be corrected and the study repeated to confirm stable operation of the network and connecting plant.

Where the instability is attributable to the connecting plant, investigate and address the issue through control retuning or other appropriate measures.

Overvoltages observed in the responses

Assess transient and retained overvoltages for each type of unbalanced fault. To avoid undesirable phase voltages above 1.1 p.u., investigate model and control tuning to minimise overvoltages where practical. Your CSR must clearly document this assessment and demonstrate that the relevant model parameters and control settings have been optimally tuned to minimise overvoltages.

5.7 Responses to disturbances following contingency events – S5.2.5.5A

5.7.1 Expectations and acceptance criteria

NER Clause S5.2.5.5A requires connecting plant to respond appropriately to disturbances during and following contingency events to support voltage recovery and stable power system operation. This includes demonstrating appropriate active and reactive current responses during and following disturbances, while maintaining stable plant operation.

What you need to do

- Use studies to demonstrate that the plant can remain in CUO while providing fast, stable and adequately controlled voltage support during undervoltage and overvoltage events. The same studies can be used to demonstrate compliance with both NER clauses S5.2.5.5 and S5.2.5.5A, provided the required assessment criteria and results are included for each clause.
- Assess the plant's response against the applicable AAS criteria, including:
  - Additional positive-sequence capacitive reactive current injection of at least 4% of maximum continuous current for each 1% reduction in positive-sequence voltage at the Connection Point below 85% of nominal voltage
  - Additional positive-sequence inductive reactive current injection of at least 6% of maximum continuous current for each 1% increase in positive-sequence voltage at the Connection Point above 115% of nominal voltage
  - Recovery of active power to at least 95% of its pre-disturbance level within 100 ms
  - A reactive current rise time of no more than 40 ms
  - A reactive current commencement time of no more than 10 ms
  - An adequately controlled reactive current response.
- Where the plant cannot meet the AAS, provide a detailed explanation supported by response plots and sufficient investigation to demonstrate the plant has been optimally tuned for the connecting location (see: CSR requirements under Section 6 for expectations on performance negotiation).

Reactive current response

- Demonstrate reactive current injection during undervoltage events and reactive current absorption during overvoltage events at the Connection Point, consistent with Figure 5-3. The assessment should:
  - Cover a representative range of balanced and unbalanced faults
  - Include all applicable active and reactive power operating scenarios
  - Identify the point at which the response saturates due to production unit reactive current limits, whether these limits apply during normal operation or FRT mode.
- Demonstrate reactive current capability using both PSS®E and PSCAD studies. Present reactive current commencement time and rise time using PSCAD studies for balanced and unbalanced faults.

The next section outlines the scope of studies required in each simulation platform.

Un-faulted phase voltage during unbalanced faults

- Demonstrate the level of voltage increase in the unfaulted phases during unbalanced faults using PSCAD studies.
- Tune the plant controls (e.g. negative-sequence current) to maintain unfaulted-phase voltages below 1.1 p.u.

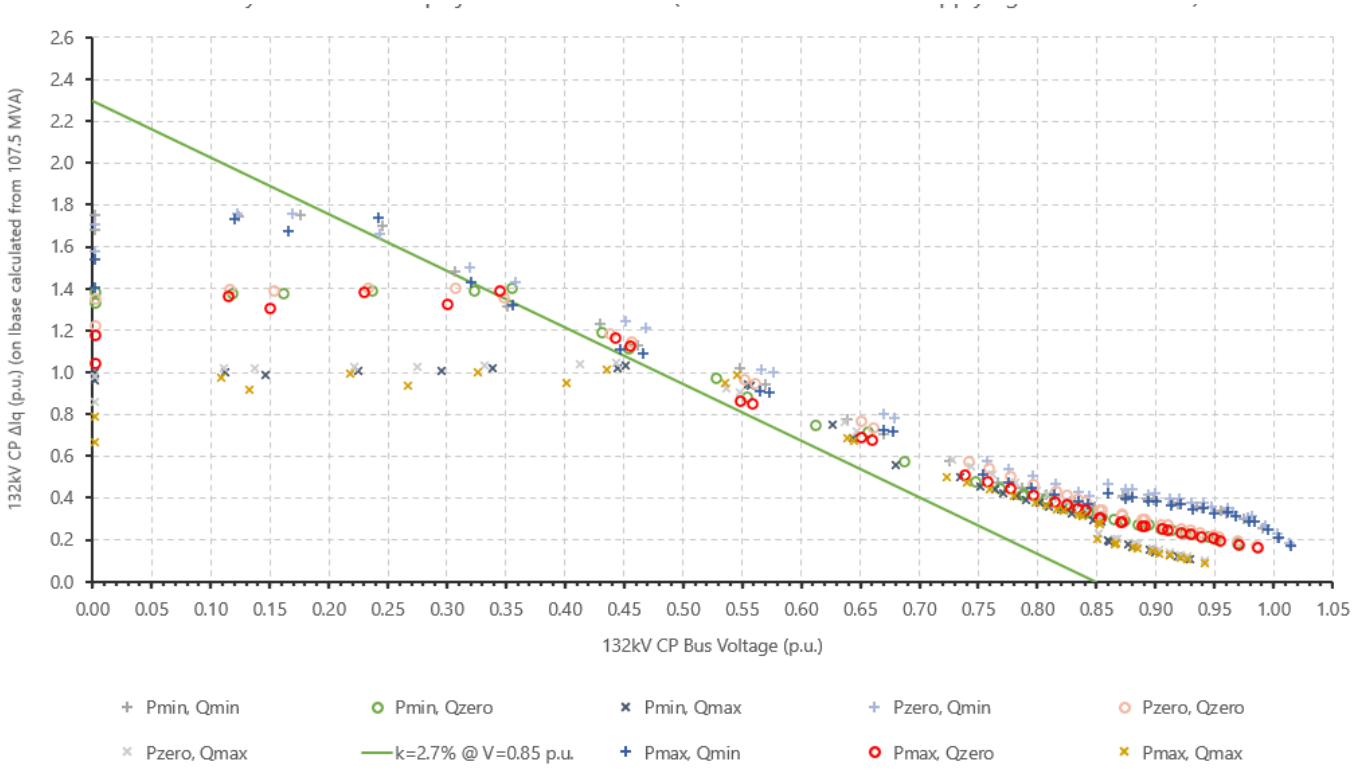


Figure 5-3 Example graph showing the magnitude of reactive current injection at the Connection Point

Post fault response

- Demonstrate the active power recovery time following fault clearance,14 using the SMIB and NEM studies.

Negative sequence reactive current injection

Because negative-sequence control strategies may vary between OEMs, your CSR must clearly describe the strategy implemented in the plant.

What you need to do

- Use PSCAD studies to demonstrate the negative-sequence reactive current response during unbalanced faults.
- Demonstrate that the strategy contributes to reducing overvoltages in the unfaulted phases while maintaining a stable and adequately controlled response at the Connection Point.

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14 NER defines the end of the disturbance as 20 ms after the last time the Connection Point voltage is outside the range 0.9 p.u. to 1.1 p.u.

5.7.2 Methodology

5.7.2.1 Scope of the PSCAD SMIB studies – single balanced and unbalanced faults

The setup and operating conditions to be used for the PSCAD SMIB studies are as per the criteria outlined in the previous section for clause S5.2.5.5 assessment.

Test requirements

- For capacitive reactive current injection assessment, apply faults with a residual voltage at the Connection Point in the range between 0.0 p.u. and 0.9 p.u. in sufficiently incremental steps to determine the reactive current injection performance.
- Similarly, for inductive reactive current injection, apply disturbances with a residual voltage at the Connection Point in the range between 1.1 p.u. and 1.3 p.u. in sufficiently incremental steps.

Measurements

At a minimum, measure and plot the following signals (in addition to the Connection Point and production unit terminal P/Q/V/frequency):

- Positive and negative sequence reactive current injection at the Connection Point and production unit terminals.
- Positive and negative sequence voltage at the Connection Point and production unit terminals.
- Individual phase rms voltages (to check for over-voltages on the un-faulted phases).
- PPC and production unit FRT/freeze flags.
- Production unit current limit activation flag (if applicable)
- Individual rms phase currents at production unit terminal (to demonstrate the current saturation of the production unit).
- Other relevant signals related to the control strategy, e.g. GFM related signals.

Active power recovery

- Calculate and record the active power recovery time at the Connection Point for each applicable disturbance.
- Present a scatter plot of active power recovery time against positive-sequence retained voltage at the Connection Point.

Reactive current injection magnitude

- Measure the positive- and negative-sequence voltages and reactive currents at the Connection Point and production unit terminals immediately before fault clearance, or at another time agreed with Transgrid.
- For grid-forming plants where reactive current (Iq) decays during a fault, consult Transgrid to agree on a project-specific measurement point for recording the Iq K-factor performance in the GPS. Regardless of the agreed measurement point, the K-factor must meet the 0% MAS requirement when measured immediately before fault clearance, using the longest CBF clearance time applicable to the surrounding network.
- Tabulate and present the results in the graphical format shown in Figure 5-3 (ΔIq as a function of the positive sequence voltage curve). Clearly identify the points where the production unit current levels are saturated. (All the unsaturated points in the graph are expected to be above the curve for the proposed access standard.)

Reactive current rise time

- Calculate the positive-sequence reactive current rise time at both the Connection Point and production unit terminals.
- Use a time scale that clearly demonstrates the calculated rise time. See Figure 5-4 for further guidance on rise time calculation.

Reactive current commencement time

- Measure the commencement time from the instance where the proposed initiating condition is satisfied to the point where the reactive current reaches 10% of mean sustained value (where the 10% threshold is based on the rise time calculation).
- Calculate and plot the commencement time for positive sequence reactive current injection at both Connection Point and the production unit terminals to a scale that is sufficient to clearly demonstrate the commencement time. See Figure 5-5 for further guidance on commencement time calculation.

How to present your results

- Use scatter plots to present performance against retained fault voltage depth.
- Use box-and-whisker plots to present the un-faulted phase voltages for unbalanced faults, to assess any over-voltages on the un-faulted phases.
- Tabulate the results in MS Excel (or similar), so the level of reactive current injection can be filtered and assessed.
- Only consider cases where the reactive current response initiating condition is satisfied.
- Note that active power recovery calculation has separate requirements according to the NER.

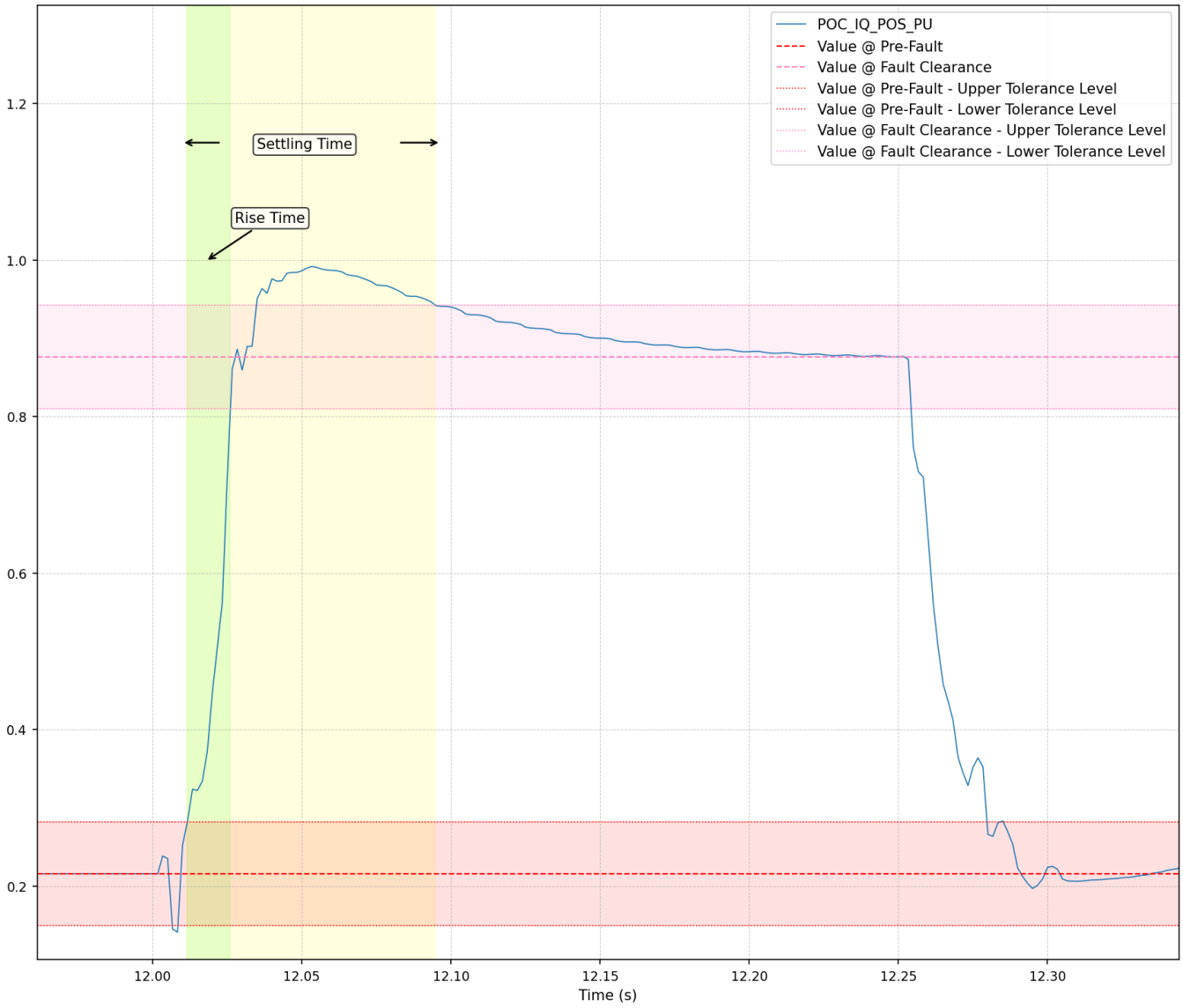


Figure 5-4: Rise time demonstration

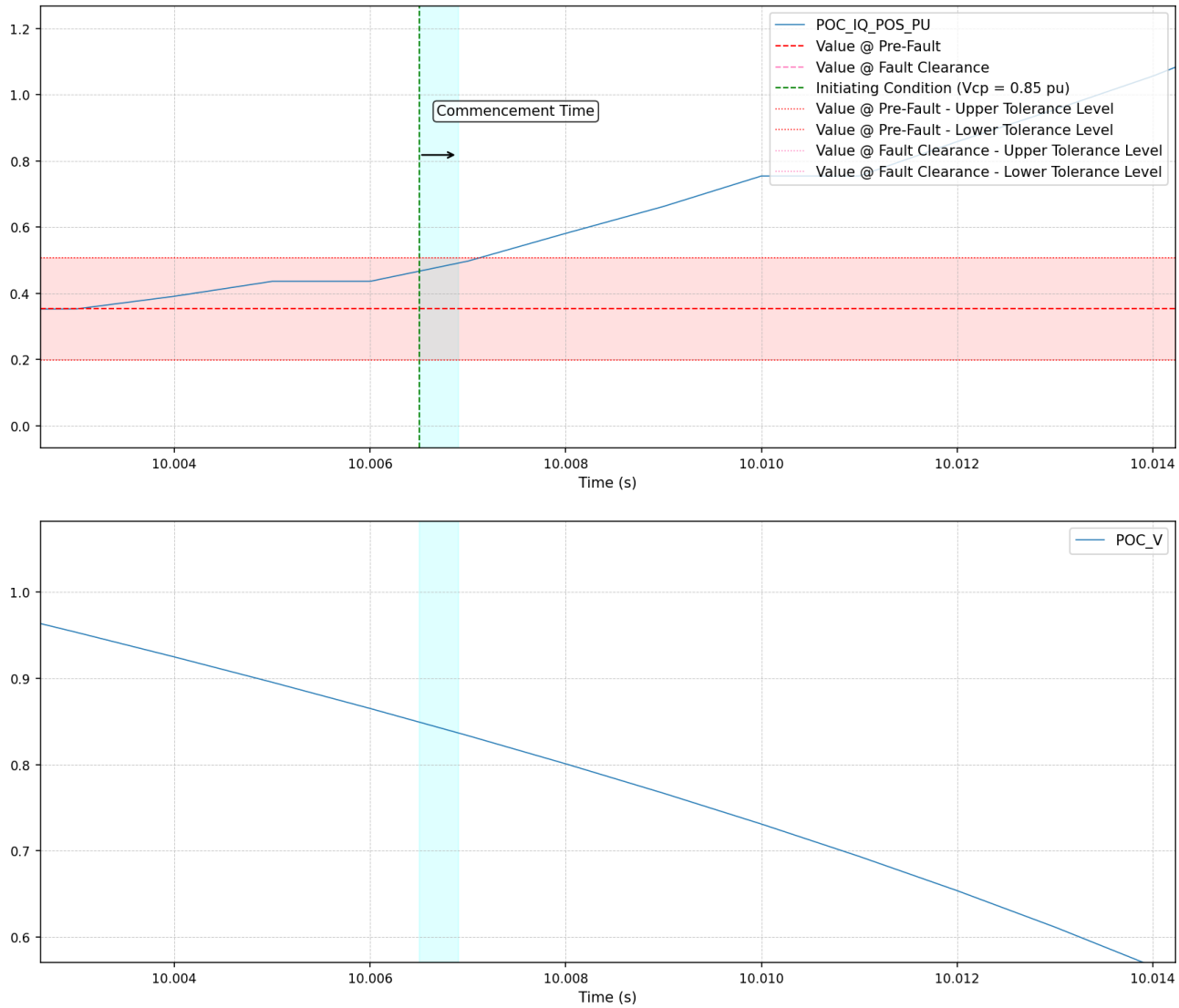


Figure 5-5: Commencement time demonstration

5.7.2.2 Scope of the PSS®E SMIB studies – single balanced faults

- Use PSS®E SMIB simulations for balanced faults to demonstrate the performance of the PSS®E model, using an approach consistent with the PSCAD assessment.

Note: Where sufficient evidence is provided through the DMAT and model benchmarking, the reduced operating scenarios specified in Table 5-10 may be used. Studies undertaken under Section 5.6.2.4 may also be used for this assessment, provided the required signals and performance metrics are included.

5.7.2.3 Scope of the PSS®E NEM studies – single balanced contingencies

Section 5.6.2.1 describes the setup of the PSS®E NEM base cases and the applicable contingency studies.

- For each PSS®E NEM simulation, calculate and present the active power recovery time at the Connection Point.

Common issues, considerations and recommendations

Active power recovery time of NEM results

In the PSS®E NEM studies, transient variations can appear in the network frequency after the faults are cleared. This can impact the plant's active power recovery, especially for grid forming inverters. If the NEM studies show significantly higher active power recovery times compared to SMIB studies, investigate the root cause(s) and report the issue and the results in the CSR. This must include whether the active power recovery time is exacerbated by concurrent network frequency events or similar phenomena for the relevant contingencies.

Active power recovery – BESS charging versus discharging

Present the active power recovery results for charging and discharging cases separately as significant differences are observed in certain scenarios. Additional breakdowns of operating scenarios and test conditions can be presented, where relevant.

Outlier cases for reactive current response/ active power recovery time

Present the rise times, commencement times or active power recovery times as percentile/scatter plots if a few outliers are significantly longer. This can demonstrate whether the majority of cases are compliant if the studies cover the full range of Connection Point voltages for the variation of fault depths considered.

5.8 Response to abnormal voltage quality – S5.2.5.6

The NER clause S5.2.5.6 requires the plant to 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 limits specified in S5.1a. The CPTSR specifies these requirements as they apply to the connecting plant.

What you need to do

- Obtain an OEM statement of compliance confirming that the plant meets the requirements of S5.2.5.6. If the OEM cannot provide this statement, additional evidence, such as Factory Acceptance Test (FAT) results may be required.
- Update the proposed performance standard in the GPS for S5.2.5.6 to incorporate the applicable limits specified in the CPTSR.

Note: Transgrid applies a margin to the planning levels for voltage fluctuations and harmonic voltage distortion when setting these quality of supply limits. The margin provides operational headroom and reduces the likelihood of plant disconnection during infrequent events where power quality levels can exceed the applicable planning levels.

5.9 Partial load rejection for synchronous production units – S5.2.5.7

The partial-load rejection requirements in NER S5.2.5.7 only apply to synchronous generation. As the scope of this Guide is limited to the requirements for asynchronous plant, partial-load rejection requirements are not addressed.

5.10 Protection from power system disturbances – S5.2.5.8

5.10.1 Expectations and acceptance criteria

NER Clause S5.2.5.8 requires protection and control systems to be coordinated with the agreed performance standards so the plant is not unnecessarily disconnected during power system disturbances. This includes demonstrating that protection systems operate only for conditions where disconnection is required and remain stable for disturbances that the plant is required to withstand.

What you need to do

- Ensure that the GPS records:
  - conditions where the plant must not trip, where otherwise it would be allowed under the performance standards to disconnect
  - conditions where it must disconnect, where otherwise it must remain in CUO
  - anti-islanding trip schemes, special protection schemes (SPS) and emergency control schemes.
- Demonstrate plant performance under extreme frequency excursions using a SMIB model to show that the:
  - plant reduces its active power by 50% of its pre disturbance level for over frequency events which exceeds the threshold of 0.5 Hz below the upper limit of the extreme frequency excursion tolerance limit15 within 3 seconds;
  - voltage and frequency protection activate in both the PSCAD and PSS®E models for each protection range
  - plant does not trip for a sudden voltage phase angle shift of 20 degrees at the Connection Point.

5.10.2 Methodology

5.10.2.1 Response to frequency disturbance

- Perform a frequency disturbance test at or slightly above 51.5 Hz at the maximum active power.
- Report the time taken for the active power to drop by 50%, which should be less than 3 seconds.

15 This corresponds to 51.5 Hz based on the current frequency operating standards effective from 9th October 2023.

5.10.2.2 Protection System

- Perform voltage and frequency disturbance tests to drive the voltage or frequency at the production unit terminals to the respective voltage and frequency protection thresholds.
- Repeat these tests using both the PSS®E and PSCAD SMIB models with each test simulated sufficiently long to demonstrate that the plant trips at the appropriate protection setting.
- Include plots of each test showing the corresponding trip flags of the production unit, if they are available.

5.10.3 Voltage phase shift test

- Include any vector shift or similar protections used in the plant in both the PSCAD and PSS®E models.
- Perform the voltage phase shift test at the minimum SCR with a step change of 20 degrees to the phase angle of the SMIB voltage. (The plant should ride through the disturbance and return to the pre disturbance voltage, active power and reactive power levels.)
- Repeat the tests using both the PSS®E and PSCAD SMIB models.

5.11 Protection systems that impact on power system security – S5.2.5.9

NER Clause S5.2.5.9 requires the plant to be equipped with protection systems that detect and clear faults within the required timeframes while minimising impacts on power system security. This includes demonstrating that protection systems are appropriately coordinated, reliable, and incorporate suitable redundancy where required.

What you need to do

- Propose the applicable fault clearance times for primary protection, back-up protection, and breaker failure protection systems across the entire generating system as part of the proposed GPS.
- Ensure fault clearance times for high and medium voltage protection systems comply with the system standards specified in clause S5.1a.8.
- Specify fault clearance times for low voltage protection systems based on the proposed plant design and included in the GPS.

Note: given that more accurate protection clearance time information may only become available during the detailed design phase, fault clearance times recorded in the GPS at the R1 stage can be updated.

5.12 Detection and response to unstable operation – S5.2.5.10

Connecting plant must meet the requirements specified under NER clause S5.2.5.10. This includes being able to:

- Detect connecting plant's voltage, reactive power and active power instability at the Connection Point
- Disconnect units for unstable behaviour, with configurable enablement conditions and settings agreed with Transgrid and AEMO
- Upon detecting a plant instability, promptly execute a hierarchy of actions based on configurable trigger conditions, thresholds, and time frames agreed with Transgrid and AEMO.
- Communicate information from its detection system to Transgrid and AEMO control centre(s)
- Receive a remote tripping signal from Transgrid.

Further information on Transgrid's specific requirements applicable for any instability detection scheme is available in the *Instability Monitoring System Guide for Asynchronous Generators* – see the Commissioning Package provided with your Data Response.

For production systems with an active power capability of 100 MW or greater, the plant must:

- Have access to a phasor measurement unit (PMU) capable of providing system data to both AEMO and Transgrid
- Be capable of receiving information from AEMO regarding the system's contribution to instability, where such information is available and provided in a format nominated by AEMO.

5.13 Frequency control – S5.2.5.11

5.13.1 Expectations and acceptance criteria

Under NER S5.2.5.11, a connecting plant must demonstrate that its frequency control system can automatically and appropriately vary active power output in response to power system frequency disturbances, to support power system frequency stability. The plant must provide its frequency response in accordance with the specified droop and deadband settings.

What you need to do

- Provide assessments demonstrating that the plant's active power response:
  - Follows the specified droop and deadband for both under-frequency and over-frequency disturbances. Is stable and remains unchanged for disturbances where the frequency remains within the frequency deadbandRemains within the active power limits for both under-frequency and over-frequency disturbances.
- Provide a:
  - Table of droop calculations for a range of frequency steps
  - Graph comparing theoretically calculated active power response at the Connection Point with the simulated active power response
- Where an integrated resource system is proposing to participate in the FCAS market, demonstrate the operation of the plant with a droop setting of 1.7%, or the alternative droop setting proposed for operation.16

5.13.2 Methodology

- Assess the frequency control of the plant using both PSS®E and PSCAD SMIB models.
- Conduct tests for all the applicable combinations of operating scenarios in Section 5.1.

16 At present, AEMO will accept a droop setting as low as 1.7% for an integrated resource system that is proposing to participate in the FCAS market.

- For the frequency droop assessment, simulate the frequency disturbances in Table 5-11 with a frequency ramp rate of 1 Hz/s considering the dispatch scenarios specified in Section 5.1.
- Perform at least disturbances of 52Hz, 51Hz, 49Hz and 47Hz considering Q_{max} and Q_{min} dispatch scenarios in PSCAD17. (Perform the rest of the PSCAD and all PSS®E studies considering the Q_{zero} dispatch condition.)

Note: The disturbances may be performed sequentially or individually, with the ramp rate applied until the target frequency is reached. If the droop implemented has more than one gradient (two or more staged droop response), select frequency steps to assess each stage of the droop response.

Table 5-11 Frequency control disturbances

Disturbance	Frequency [Hz]
1	52.0
2	51.5
3	51.0
4	50.5
5	50.1
6	50.02
7	50.01
8	49.99
9	49.98
10	49.9
11	49.5
12	49.0
13	48.5
14	48.0
15	47.0

17 If S5.2.5.3 studies were not conducted in PSCAD considering Q_{max} and Q_{min} dispatches. Otherwise, all the tests can be performed considering Q_{zero} dispatch

Note: The duration of each frequency disturbance must be sufficiently long to allow the active power response to settle. The steady state measurements of frequency and active power must be recorded and compared against the expected response based on the specified droop. Measurements must be provided as an Excel attachment.

Common issues, considerations and recommendations

Unstable frequency response during very low SCR scenarios

If unstable plant responses are observed in SMIB studies for extreme frequency disturbances, such as 48 Hz or 52 Hz, further investigations must be undertaken and presented in the CSR. See "Common issues, considerations and recommendations" in Section 5.4 for further guidance.

5.14 Impact on network capability – S5.2.5.12

5.14.1 Expectations and acceptance criteria

NER Clause S5.2.5.12 requires the plant to be designed and operated so that it does not adversely impact network capability or power transfer capability. This includes demonstrating that the plant's capabilities, control systems and operational arrangements minimise constraints on the existing network while maintaining power system security.

What you need to do

- Perform both steady state and dynamic studies using the PSS®E NEM model to demonstrate that the plant connection will not adversely impact capabilities of the transmission network – and that the connection will not reduce intra-regional or inter-regional power transfer capability.
- For the applicable network contingencies, assess impacts on:
  - Thermal loading of transmission lines and transformers
  - Network voltages and voltage step changes
  - Power system stability.

5.14.2 Methodology

- Ensure the PSS®E NEM model base case is stable before assessing the impact of connecting the proposed new plant (see Section 4.10).
- Use the list of contingencies and the fault clearance times in the Regional Network Data document(s). Consider:
  - All contingencies up to at least three buses away in the main system for potential Connection Points in the 330 kV or 500 kV transmission system.
  - Additional contingencies in the nearby network for Connection Points in the sub-transmission network.

- For plant connecting close to the Queensland or Victoria networks
  - Consider a range of contingencies in the nearby region. Assume the standard clearance times in NER S5.1a.8 unless otherwise specified by Transgrid or AEMO.
- For plant connecting to the main system
  - Consider tripping the largest generator and the largest load in NSW or Queensland.
- For plant connecting close to a bulk supply point
  - Consider contingencies in the distribution network. Request information from Transgrid using the RFI process.
- Take into account any special protection schemes (SPS) associated with the committed and in-service generators. SPS details are included in the Regional Network Data document.

5.14.3 Steady State Assessment

- Set up the steady state PSS®E NEM study cases so the connecting plant is at its maximum output, including maximum charging and discharging for a connecting BESS.
- Dispatch the nearby generators and BESS so nearby transformer and transmission line loadings under system normal conditions are less than or equal to the continuous rating.
- To assess the network performance under N-1 conditions, disconnect a single network element (a transmission line or transformer), the largest generator and the largest load and solve the load flow with both OLTCs and switch shunts locked and the loading of the network elements in the region.
- Record all nearby bus voltages and bus voltage changes.
- Assess and record a wide range of different network N-1 conditions for all nearby major elements.
- Study each contingency with and without the connecting plant in service.
- Analyse each element below to assess the impact of addition of the plant on the network.

Thermal capacity

- Ensure the transmission line and transformer loadings under N-1 conditions are less than or equal to the contingency rating using the ratings listed in the relevant Data Response.
- Provide a comparison of line and transformer loadings with and without the plant in service.
- Identify any thermal capacity issues caused by the plant.

Bus voltage

- Ensure all the bus voltages in the relevant region are in the range 0.9 p.u. to 1.1 p.u. under system normal conditions and N-1 condition[18] or otherwise stated in the relevant Regional Network Data document.

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18 If the voltage droop response of nearby plants were not properly considered in PSS®E load flow this may not be achievable in N-1 condition (i.e., post contingency). In such cases, provide an explanation in the CSR and consider the dynamic performance obtained under clause S5.2.5.5/S5.2.5.5A.

Step change in voltage

- Assess the step change to the voltages at the nearby buses in the region for each N-1 contingency, with and without the plant in service.
- The voltage changes should be less than or equal to:[18]
  - 10% for contingencies of transmission line or transformer
  - 5% for large generator trip.

Step change in voltage for tripping the proposed connection

- Assess the size of the step voltage change for the tripping the proposed connecting generator. (The size of the voltage step should be less than 5%.[18])

5.14.4 Dynamic assessment

Contingency assessment

- In addition to the steady-state assessment, perform dynamic studies for each scenario and contingency discussed above.
- Results can be reused from studies already been completed for the NER clause S5.2.5.5 assessment, provided they include the signals specified under 'Results and Plotting' below.

Impact on power transfer capability

- Use dynamic studies to assess the impact of the connecting plant on relevant inter-regional or intra-regional power transfer limits.
- Perform the following assessment both with and without the connecting plant in service:
  - Adjust the generation dispatch so that the interconnector flow is close to the relevant stability limit (i.e., marginally stable conditions).
  - Simulate the critical credible contingency event/s associated with the power transfer limit. See AEMO's *interconnector capability document* and Transgrid OMs in the Data Response for the relevant limit and the associated critical contingency event/s.
  - Where the critical contingency involves large generator or load trip events, conduct studies both with and without a fault applied prior to the trip event.
  - Adjust the generation dispatch to increase the interconnector flow in steps of approximately 20 MW and repeat the simulation of the critical contingency event. Repeat until the system is unstable.
  - Present the plots of the dynamic studies including both marginally stable and unstable scenarios.
- Perform the stability-limit assessment for both directions of power flow:
  - AAS: the power transfer limit with the connecting plant in service must be equal to or greater than the corresponding limit without the plant in service in each direction.
  - MAS: the reduction in the power transfer limit with the connecting plant in service must not exceed the combined sent-out generation of the plant's production units.

How to present your results

- For all dynamic assessments for this clause, include plots of the:
  - voltage of nearby busbars
  - power flow in the nearby network
  - rotor angle for nearby large synchronous generating units, large NSW synchronous generating units and one or two large generators on the other region (i.e. QLD or VIC depending on the interconnector under study).

Common issues, considerations and recommendations

Impact on inter- or intra-regional power transfer limits

The connecting plant will not comply with the AAS for NER clause S5.2.5.12 if it reduces any relevant power transfer limit. If a reduction is identified, consult AEMO and Transgrid to determine whether a negotiated performance standard may be acceptable.

Note: negotiating the performance standard for NER clause S5.2.5.12 may require additional dynamic studies to:

- Further assess the likely impact of the reduction in power transfer capability
- Demonstrate whether the plant can meet the MAS.

5.15 Voltage and reactive power control – S5.2.5.13

5.15.1 Expectation and acceptance criteria

Under NER S5.2.5.13, a connecting plant must demonstrate that its control system can regulate voltage, reactive power and/or power factor, and respond appropriately to network disturbances, setpoint changes and changing power system conditions within the required response time and accuracy requirements, to support voltage stability and secure network operation.

What you need to do

- Demonstrate stable and adequately damped control system performance across the expected operating range, such that it:
  - Does not degrade the damping of any critical mode of oscillation of the power system
  - Does not cause instability in voltage, reactive power or active power within the power system.

Primary and secondary control models

The assessment methodologies and acceptance criteria in this Guide are based on using voltage droop control as the primary voltage control mode and reactive power control as the secondary mode. If you propose using an alternative primary or secondary control mode, consult Transgrid and AEMO before submitting your Connection Application.

What you need to do

- Configure your plant's control system to operate in voltage droop control mode and regulate voltage in accordance with the following requirements:
  - Voltage setpoint must be continuously controllable over a range of at least ±5% of nominal voltage above and below the target voltage determined by Transgrid19.
  - Voltage droop must be 12.7% on a rated MW base (expressed in MVA).
  - Where the plant is operating with a reduced number of production units in-service (for example, if some of the inverters or wind turbine generators are out-of-service), scale the droop base (in MW measured at the Connection Point) in proportion to the number of in-service production units while maintaining the 12.7% droop setting.
- Demonstrate an adequately damped20 response for setpoint changes and voltage disturbances in both primary and secondary control modes.
  - Check the Supplementary Report for additional project-specific requirements for voltage and reactive power control, including any remote voltage control point requirements.
- Document all assessment results described in Section 5.15.2 in the CSR, which must include:
  - A summary of the results
  - Detailed results in a tabular format or in an Excel file as an attachment (or equivalent).

Partial operation

- To verify plant operation with reduced number of production units in-service, perform a limited assessment of the voltage droop control with 50% of the production units in-service. The assessment must demonstrate that:
  - voltage droop is maintained at 12.7% with the droop base scaled to 50% of plant's rated MW capacity
  - the reactive power limits are scaled proportionally to reflect the reduced number of production units in service.
- Capture the modelling instructions for partial operation in the RUGs as outlined in Section 4.4.3.

5.15.2 Methodology

- Assess the plant's voltage and reactive power control performance under typical and maximum impedance across a range of operating scenarios, as specified in Section 5.1.

Scope of the PSS®E and PSCAD SMIB studies

19 NER S5.2.5.13 requires that the target voltage be determined by the Network Service Provider in accordance with clause S5.1.4(c).

20 Please see the applicable "adequately damped" criteria in NER Chapter 10 – Glossary.

- Complete the full scope of assessments in PSS®E, including SMIB studies and wide-area NEM studies based on OPDMS snapshots
- Undertake a limited set of SMIB assessments in PSCAD. At a minimum, include limiter tests for voltage setpoint changes and voltage disturbances in voltage droop control mode.

Voltage droop assessment

- Validate the plant's voltage droop settings through voltage setpoint or voltage disturbance response. This can be demonstrated by:
  - applying a series of incremental voltage disturbances at the voltage source across the normal operating range of the PPC or
  - directly applying a series of voltage setpoints to the PPC.
- At each test level, record the steady-state voltage and reactive power measurements and assess them against the expected voltage droop response.
- Tabulate voltage and reactive power measurements in Excel (or other equivalent format).

Voltage setpoint changes

Non-limiter tests and limiter tests are required, depending on the initial reactive power conditions.

- For non-limiter tests apply, ±5% voltage setpoint changes, including the return step, through the PPC model. At a minimum, test:
  - ±5% voltage setpoint changes for Q_{ZERO} cases
  - -5% for Q_{MAX} cases
  - +5% for Q_{MIN} cases.
- For limiter tests, apply ±2.5% voltage setpoint changes through the PPC to step away from the reactive power limit, followed by a further ± 5% voltage setpoint step change into the reactive power limit.
- Include detailed plots for each test in the CSR.
- Calculate the settling times for voltage, reactive power and active power at the Connection Point using the applicable NER definitions.
- Present the results in the CSR to demonstrate the accuracy (present the voltage control error in the form of the equations below) of the PPC in achieving the target setpoint.
- $Voltage\ control\ error = \left|\frac{V_{expected\ at\ CP} - V_{measured\ at\ CP}}{V_{expected\ at\ CP}}\right| \times 100\%$
- $V_{expected\ at\ CP} = V_{setpoint} - \frac{droop \times Q_{measured\ at\ CP}}{droop\ base}$

Voltage disturbances (voltage droop control mode)

- Apply voltage disturbances of ±5% to the SMIB voltage source via a voltage playback, with the plant operating in voltage droop mode.
- Adjust the disturbance applied at the SMIB voltage source as needed to achieve a voltage change of between ±2% and ±5% at the Connection Point. Alternatively, apply a shunt at the Connection Point to produce the required disturbance magnitude.
- For non-limiter tests, apply the following grid voltage disturbances, including the return step:
  - ±5% and return steps for Q_{ZERO} cases
  - +5% for Q_{MAX} cases
  - -5% for Q_{MIN} cases.

- For the limiter tests:
  - Initialise the plant at the applicable reactive power limit at the Connection Point.
  - Apply a ±2.5% grid voltage change to step away from the limit
  - Follow this with a further 5% grid voltage step change into that same limit.
- Calculate the rise time21 of reactive power and settling times for Connection Point voltage, reactive power and active power using the applicable NER definitions under both typical and the highest system impedance scenarios.

Reactive power setpoint changes

Both non-limiter tests and limiter tests are required, depending on the initial reactive power conditions.

- Perform these tests using the typical system impedance conditions.
- Switch the PPC to reactive power control mode and ±0.5 p.u. of the reactive power range established under clause S5.2.5.1 of the performance standards (i.e., apply a reactive power setpoint step size of 100% of Q_{MAX} or Q_{MIN} via the PPC model).
- Calculate reactive power settling times using the applicable NER definition.
- Present the results in the CSR to demonstrate the accuracy of the plant reactive power response in achieving the target setpoint.

Voltage disturbances (reactive power control mode)

- Apply voltage disturbances of ±5% to the SMIB voltage source under typical system impedance conditions, with the plant operating in reactive power control mode.
- Calculate the settling times for reactive power using the applicable NER definition.

NEM wide PSS®E studies

- Set up the PSS®E base cases so that the Connection Point voltage and reactive power conditions are suitable for assessing both non-limiter and limiter operation.
- For each of the PSS®E NEM base cases described in Section 4.10, perform the following tests in both the primary control mode (voltage droop control) and the secondary control mode:
  - ±5% voltage setpoint changes
  - voltage disturbances in the range of ±2% to ±5%, applied by switching a ficticious capacitor or reactor at the Connection Point
- Assess the response of the plant to switching of nearby reactive plant
- Report the corresponding rise time and settling time in the CSR.

21 Rise time assessment is only applicable for voltage disturbances where the limiter is not activated.

Limiter testing

Alternative methodologies can be used to assess limiter operation. For example, Transgrid uses the following methodology to assess reactive power limiter performance:

- Apply a 2.5% voltage step to step away from the limiter operating point and allow the plant to reach steady-state operation. This may require at least 10 seconds or longer.
- Configure the system so that steady state solution is achieved before applying the step into the limiter, taking into account any OLTC operation that may occur.
- Apply a further 5% voltage step towards the limiter operating point (i.e., a net step of 2.5% into the limiter).
- Assess the plant response, including limiter activation, voltage control performance, and recovery to steady-state operation.

Common issues, considerations and recommendations

Voltage instabilities at low SCR and X/R

Using the voltage playback method to simulate voltage disturbances can introduce voltage instabilities due to modelling artefact, under low SCR and X/R conditions. When such issues are observed, simulate voltage disturbances by switching shunt devices at the Connection Point to produce the required voltage change.

Interaction with nearby plant in wide-area NEM studies

When undertaking assessments for NER clause S5.2.5.13 using NEM network cases, the interactions between the connecting plant and nearby dynamic plant may contribute to prolonged response characteristics, including increased rise times and settling times. Where such interactions affect the assessment outcome, undertake suitable sensitivity studies to quantify and demonstrate the impact of the nearby plant(s). Discuss the results with Transgrid and agree on an appropriate assessment approach before finalising the study conclusions.

Performance of secondary control modes

Some OEMs employ control system architectures in which the primary and secondary control modes share a common set of control gains. In such cases, ensure that tuning changes made to improve the performance of the secondary control mode do not adversely affect or compromise the performance of the primary control mode.

Voltage drops and instability issues during low SCR conditions

5.16 Active power control – S5.2.5.14

5.16.1 Expectation and acceptance criteria

Under NER S5.2.5.14, a connecting plant must demonstrate that it can automatically increase, decrease, maintain and control active power transfer in response to dispatch instructions.

What you need to do

- Demonstrate that the plant can ramp its active power linearly between setpoints without exceeding Connection Point active power limits, based on plant's rated MW capacity.
  - this applies to all relevant operating configurations, including BESS-only, PV-only or Wind-only (as applicable) and the hybrid system as a whole, including demonstrating active power sharing between the individual parts of plant.
- Use sufficient sensitivity studies to demonstrate the:
  - general stability of the active power response
  - smooth transitions between modes, where applicable
  - operation of individual PPCs where the plant includes more than one;
  - coordination of the PPCs for each individual DUID
  - operation of the plant as a whole.
- Perform a limited assessment of active power reference step changes with the PPC active power ramp-rate limits disabled.
  - This allows the underlying dynamic response and damping characteristics of the generating system's active power controller response to be assessed independently of artificial ramp-rate constraints.

5.16.2 Methodology

- Assess the active power control of the plant using both PSCAD and PSS®E SMIB models under minimum fault level conditions.
- Test the following sequence of active power setpoints transitions as a percentage of the rated capacity of the plant:
  - 100% → 50% (discharging or generating)
  - 50%→ 0% (discharging or generating)
  - 0% → -50% (charging for BESS)
  - -50% → -100% (charging for BESS)
  - -100% → 100%, (charging to discharging/generating)

Common issues, considerations and recommendations

Voltage drops and instability issues during low SCR conditions

If the fault level and SCR at the Connection Point are low, active power step change tests using a SMIB model may lead to very large voltage variations at the Connection Point. This behaviour may result in instability and potentially trigger FRT mode. Where this occurs, undertake equivalent testing using a PSS®E NEM model with a comparable SCR maintained at the Connection Point.

Present the resulting plant response in your CSR and discuss the outcomes with Transgrid and AEMO.

5.17 Short circuit ratio – S5.2.5.15

5.17.1 Expectation and acceptance criteria

NER clause S5.2.5.15 requires inverter-based generating systems to operate stably and remain connected at the agreed short circuit ratio (SCR) at the Connection Point.

What you need to do

- Perform withstand SCR assessments using PSCAD in accordance with AEMO requirements in *Technical Note – System Strength Withstand SCR Methodology Review V2.1*.
  - Consider the requirements of Table 2 and Table 3 of AEMO's Technical Note and refer to the latest version of the SSIAGError! Bookmark not defined..
- Perform the withstand SCR under the following operating conditions, as applicable:
  - at maximum generation (for generating systems)
  - at maximum discharging and charging for BESS (taking into account AEMO's guidance on active power absorption limits for the charging scenario as per the Technical note above)
  - all applicable hybrid system scenarios specified in Section 5.1, including:
    - Hybrid operation, with the BESS charging at 100% and PV / Wind @ 100%
    - Hybrid operation at maximum active power output at the Connection Point, with PV / Wind generation output prioritised.
    - If you use different parameter settings for the Clause S5.2.5.15 assessment than those in the site-specific PSCAD model for other GPS clause assessments, document all such variations in both the Connection Study Report and the PSCAD RUG.

Common issues, considerations and recommendations

Performing studies when control point is different from Connection Point

Where voltage control is implemented at a remote location rather than at the Connection Point, you must still demonstrate compliance with the minimum SCR requirements specified in clause 5.2.5.15 at the Connection Point. If the current plant configuration makes it difficult to represent or assess the required minimum SCR at the Connection Point, discuss the proposed modelling approach with Transgrid (through an RFI) before undertaking the assessment.

5.18 Fault current – S5.2.8

5.18.1 Expectation and acceptance criteria

NER clause S5.2.8 requires the plant to be designed so that:

- Its fault current contribution is within the limits specified by the Network Service Provider
- All plant and switching equipment can safely withstand and interrupt fault current levels at the Connection Point

Transgrid's assessment of fault current contributions is based on the PowerFactory model as described in Section 4.7.2. Fault levels are calculated based on the ANSI 'momentary' fault currents method.

What you need to do

- Use the same model and calculation method to undertake the fault level assessment and propose the performance standard for NER clause S5.2.8.
- Check that the production units' fault current response is accurately represented in the PowerFactory model so that it closely reflects the expected response of the actual equipment.

The plant fault current contribution

- Calculate the fault current contributions from its plant for the following fault types:
  - Three phase fault current
  - Single phase to ground fault current
  - Phase to phase to ground fault current
- Record these fault level contributions in the GPS (the levels should be less than the limits specified in the CPTSR).

The plant equipment fault withstand capability

As specified in the CPTSR, the fault current level that the plant must be capable of withstanding through the Connection Point.

- Check that the plant equipment withstand capability specified in the GPS considers the withstand capability of the entire generating system, including the earthing grid.

The plant's circuit breaker fault current breaking capability

- Demonstrate that each circuit breaker used to isolate the plant from the network can interrupt, without damage or restrike, the maximum fault current that could reasonably flow through it for faults within the plant and faults on the transmission network.
- Consult Transgrid if the plant's circuit breaker is not capable of meeting the AAS specified in the CPTSR.

5.19 Instructions for Q-at-Night operation of solar farms and operation of wind farms below cut-in wind speed

Transgrid expects generating systems to operate in primary voltage control mode during Q-at-Night operation and when wind farms are operating below cut-in wind speed. For projects where voltage droop control is the primary control mode, the plant must operate in voltage droop control mode using the same reactive power–voltage droop settings applied during normal operation.

5.19.1 NER Clause Assessment Requirements

S5.2.5.1

These operating modes must be considered when establishing the reactive power capability of the generating system. The applicable reactive power capability under each operating mode must be specified in the GPS

S5.2.5.2

To comply with Clause S5.2.5.2, when conducting the harmonic assessments of the plant you must consider Q-at-Night operation of solar farms and operation of wind farms below cut-in wind speed (see Transgrid's *Attachment 2 - Harmonic Assessment Requirements*).

S5.2.5.5

The following limited studies must be conducted at the minimum fault level at the Connection Point in both Qmax and Qmin:[22]

- A three-phase fault at the PoC, cleared within primary protection clearing times.
- A line-to-line-to-ground fault at the PoC, cleared within circuit-breaker failure protection clearing times.

22Qmax and Qmin is the Qmax and Qmin applicable under Q-at-night operation/operation below cut-in wind speed as established in Clause S5.2.5.1 assessments

S5.2.5.13

Assessments must be conducted to demonstrate compliance with Clause S5.2.5.13, as required by NER clause S5.1.5.1(h)(1), demonstrating the compliance with the applicable settling-time requirements.

Other Clause Assessments

As required by the NER Clause S5.2.5.1(h)(2), these operating modes must also be considered when establishing performance standards for the following clauses:

- S5.2.5.9, S5.2.5.10, S5.2.5.15, S5.2.6.1 and S5.2.6.2
- S5.2.5.8, in relation to the applicable protection requirements

Chapter 6

Connection application submission

The quality, completeness and consistency of your submission directly influence assessment timeframes. Missing, incomplete or inconsistent information may result in requests for further information and repeated review cycles, increasing both assessment timeframes and costs. This section covers areas where submissions frequently have information gaps.

What you need to do

- Provide the Connection Application submission in the *Attachment 4 - Connection Application Folder Structure*.
- Complete the *Submission Checklist* as part of your submission to confirm that all critical information required for acceptance is included.
- Check that your submission follows the guidance below on components of the Connection Application where submissions often fall short.

Generator Performance Standards (GPS)

- Check that your proposed negotiated performance standard:
  - is set at a level that will not adversely affect power system security, quality of supply for other Network Users, or achievement of the system standards
  - meets the requirements for a Negotiated Access Standard for the relevant technical requirement under Schedule 5.2 (NER clause 5.3.4A sets out the requirements that must be met)
  - is as close as practicable to the Automatic Access Standard (AAS), bearing in mind the importance of protecting plant from damage, power system conditions at your connecting location and the technical and commercial feasibility of meeting the AAS.

Connections Study Report (CSR)

- Check that your CSR provides a clear and comprehensive assessment of the proposed plant performance, explains why the proposed performance standard is appropriate for the connecting location and demonstrates how compliance with the applicable requirements of the NER will be achieved.

Your CSR should:

- Provide sufficient technical justification to demonstrate that the plant has been optimally tuned for the connecting location, and that further improvements in performance are not reasonably achievable, considering, where relevant:
  - network strength and system operating conditions
  - the performance and dynamic behaviour of nearby generating systems and network-connected equipment
  - plant technology and control system architecture
  - manufacturer design constraints and equipment capability limits
  - stability, control coordination and protection requirements
  - compliance with other GPS clauses
  - operational reliability and power system security considerations.
- Provide clear evidence of the plant tuning methodology and associated outcomes, either in a dedicated tuning report or within the CSR, including:
  - a clear description of the tuning approach and modelling assumptions, control parameter selection, assessment methodology and resulting plant performance.
  - simulation results with plots

- comparative assessments demonstrating the performance achieved under the recommended tuning options.
- sensitivity studies assessing the impact of changes in critical parameters that materially influence the plant performance, such as controller gains, limits, and other key settings.

- Check that the evidence provides a sufficient basis for concluding that the proposed plant settings and the associated performance outcome represent the optimal achievable performance of the connecting plant for the connecting location. The evidence should take into account performance, stability, robustness and compliance across the credible operating scenarios and technical requirements considered in the GPS assessment.

System Strength Election Form

- Submit a completed and signed System Strength Election Form to Transgrid as per the template provided in *Attachment 4 - Connection Application Folder Structure*.

Models

- Provide:
  - site-specific PSS®E and PSCAD models for the proposed plant in accordance with the requirements set out in Section 4.
  - a DIgSILENT PowerFactory model to support harmonics, fault current, and protection assessments as outlined in Section 4.7.

Model Change Log

- Provide a model change log with each revised model submission, identifying all modifications to the PSS®E and PSCAD models since the previous version. This includes changes to:
  - plant parameters
  - control systems
  - protection settings
  - model structure
  - assumptions
  - bug fixes
- Provide an assessment of any impacts on previously submitted study results and conclusions.

Parameter Mapping Sheets

- Provide a parameter mapping sheet for the submitted PSS®E and PSCAD model, listing each model parameter and demonstrating alignment between the:
  - submitted models
  - OEM documentation
  - equipment settings
  - performance standards
  - study assumptions.

- Where a direct mapping between the two platforms is not feasible, provide a brief explanation of the discrepancy.

Project Tracker

- Use the Project Tracker template in *Attachment 4 - Connection Application Folder Structure*
- Pre-fill the *VCS Checklist* and *DMAT Checklist* tabs of the project tracker.

Power Quality Report & Model

- Submit a Power Quality Report and an associated model in DIgSILENT PowerFactory used for the assessment. See Section 4.7 for more details.

Voltage Control Strategy (VCS)

- Submit a VCS document describing how voltage and reactive power will be controlled to achieve compliance with the applicable performance standards and network requirements.
- See Section 3.1 and *Attachment 7 - VCS Report Requirements - TransGrid Guide* in the Data Response.

Functional Block Diagrams

- Either submit these as part of your CSR or
- Ask your OEMs to share functional block diagrams directly with Transgrid.

PSS®E & PSCAD RUGs

- Submit PSS®E and PSCAD RUGs for the PSS®E and PSCAD models provided as part of the connection application.
- See Sections 4.4 and 4.6 for detailed guidance.

PSS®E and PSCAD DMAT

- At a minimum, complete all mandatory tests specified in the latest version of AEMO's *DMAT Guideline*.
- Clearly identify any omitted tests and explain the reason for their omission.
- Where a bespoke model has been developed, undertake the full suite of tests outlined in the DMAT Guideline to provide a more comprehensive validation of model performance and robustness.

Note: AEMO and/or Transgrid may request additional tests depending on their assessment of the submitted DMAT results.

PSS®E and PSCAD Benchmarking

- Include a Model Benchmarking report with analysis on any misalignments observed between the PSS®E and PSCAD results.
- At minimum, submit PSS®E and PSCAD benchmarking results for the minimum set of mandatory tests specified in the DMAT Guideline.
- The benchmarking results must include:
  - relevant quantities measured at both the Connection Point and plant terminals for the PSS®E and PSCAD models
  - error bands applied to the PSCAD model response
  - an explanation for any material differences between the two model responses, where relevant.

Transgrid

Assessment of the Connection Application

6.1 Overview of assessment process

Figure 7-1 provides an overview of the Connection Application assessment and approval process.

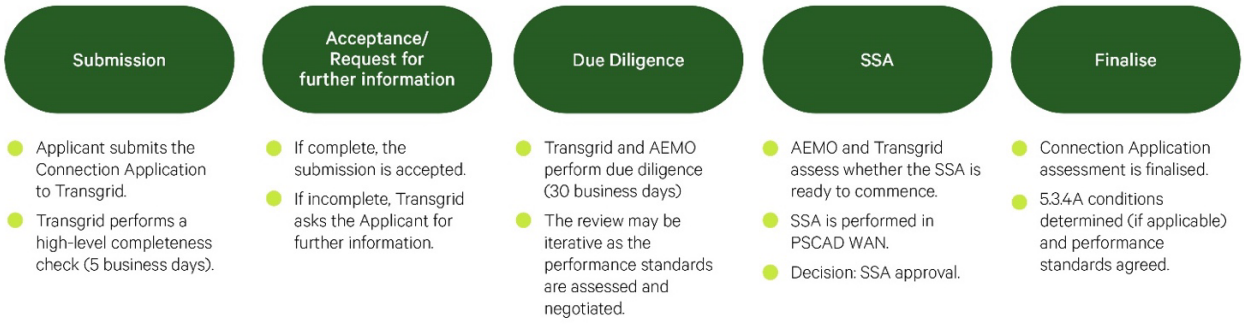


Figure 7-1 Transgrid Assessment Process

6.2 Indicative Timeframes

Table 7-1 summarises the indicative timeframes associated with the Connection Application assessment process.

Table 7-1 Connection Application Assessment Timeframes23

Activity	Indicative Timeframes
Notice periods - prior to submitting a Connection Application	• You must provide at least 4 weeks' notice before submitting a new Connection Application, to support resource planning. • This notice period also applies to any subsequent full submissions.
Completeness check	• Within 5 business days of receipt, Transgrid will undertake a completeness check and advise whether the submission has been accepted for review or whether further information is required.
Due diligence review of Connection Application submission	• Following acceptance of the submission, Transgrid will undertake its detailed due diligence review and provide a joint Transgrid/AEMO response within 30 business days. • If deficiencies are identified in the submission, further submission(s) and review rounds may be required.
Harmonic report assessment	• Transgrid will provide the outcome of the harmonic assessment within four months of the submission of the harmonic report submission. • As outlined in Section 2.6, you must submit the harmonic assessment report in advance, as early as possible before the Connection Application submission.

23 Note: the overall Connection Application approval timeframe will depend on submission quality, completeness and your response times. Multiple review rounds may be required based on the quality of the submission and identified deficiencies/issues.

Activity	Indicative Timeframes
System Strength Assessment (SSA)	• Following acceptance of the relevant PSCAD model, the SSA is expected to take approximately 8 weeks for an individual assessment and 12-14 weeks for a batch assessment, as outlined in Section 7.4.2.

6.3 Assessment of the Connection Application

6.3.1 Completeness review

On receiving a connection application submission, Transgrid undertakes an initial high-level desktop review. Within five business days, Transgrid will tell you whether the submission can be accepted for due diligence or if you need to provide additional information. Typical deficiencies identified during this review include critical missing information (see Section 6), model set up issues or other material gaps.

6.3.2 Due diligence assessment

During this detailed assessment, Transgrid and AEMO will use your submitted models and RUGs to assess whether the plant can demonstrate the proposed performance standards for each applicable technical requirement.

You will receive joint feedback within 30 business days, including a project tracker identifying documentation or plant performance elements that require further assessment, clarification or resolution. Transgrid and AEMO will also provide comments and suggested updates on the GPS document.

Address the items identified in the Project Tracker and GPS document before submitting a revised Connection Application to Transgrid. Transgrid and AEMO will review each revised submission until all critical issues for acceptance of performance standards under 5.3.4A, including critical issues relating to plant models, have been adequately addressed.

Where agreed with Transgrid and AEMO, you may resolve non-critical matters at a later stage, within a set timeframe.

6.3.3 Negotiation of performance standards

Transgrid will assess your proposed negotiated performance standard based on whether it satisfies NER clause 5.3.4A and Schedule 5.2. In consultation with AEMO, Transgrid will consider the technical evidence in your CSR, power system conditions at the Connection Point, plant capability and design constraints, the need to protect plant from damage, and the technical and commercial feasibility of achieving a higher standard.

Transgrid may reject the proposed standard or require further studies, further optimisation of plant tuning, plant modifications or an improved performance where the:

- Proposed performance level would adversely affect power system security, system standards or quality of supply for other Network Users

- Supporting evidence does not demonstrate that the proposal represents the best reasonably achievable performance for the plant at the proposed connection location.

6.4 System Strength Assessment (SSA)

Under NER 5.3.4B, Transgrid is required to undertake a SSA to assess the general system strength impact of a proposed connection.

The NER defines a general system strength impact as:

In relation to a new connection or an alteration to a generating system, integrated resource system or other connected plant, the amount equal to its adverse system strength impact as well as any additional amount by which it reduces the available fault level at the connection point for the new connection or connected plant, assessed in accordance with the system impact assessment guidelines.

- Depending on your election under NER 5.3.4B, Transgrid may undertake either a System Strength Full Assessment or a System Strength Stability Assessment. A Full Assessment will:
- Identify any adverse impacts on the network or other Network Users arising from connecting the plant
- Assess the effectiveness of any proposed System Strength Remediation Scheme (SSRS).
- Your SSA may be carried out as an individual project or as part of a batch assessment to identify potential adverse interactions between concurrently progressing projects. Batch assessments support timely commencement of SSA activities, enable more efficient use of specialist resources and allow multiple projects to progress in parallel, improving overall assessment timeframes.

6.4.1 Pre-requisites

Provide a robust PSCAD model of the plant that supports the proposed performance standards. The SSA will only commence once Transgrid and AEMO:

- Have accepted your PSCAD model, with no further model or parameter changes expected before the 5.3.4A approval process (changes may be required to address an issue identified through the SSA)
- Are satisfied that the proposed key performance standards are acceptable and the corresponding PSCAD model performance supports those performance standards.

Note: parameter changes or model updates made after Transgrid has started the SSA will likely require re-assessment, extending the time required to complete the SSA.

6.4.2 Assessment methodology and evaluation criteria

Adverse system strength impacts will be identified through a wide area network assessment using an appropriate power system model in PSCAD, in accordance with AEMO's *System Strength Impact Assessment Guidelines*.

- Evaluation criteria include that:
- The plant can successfully ride through large disturbances associated with network contingencies
- The connection does not adversely affect transient, voltage or oscillatory stability of the power system

- The connection does not degrade damping of any critical oscillatory modes, including following small or large disturbances
- No adverse effects to nearby generating systems, other network users, network-connected equipment or dynamic plant
- No unacceptable control interactions or power quality interactions are observed, including interactions that may occur without a network disturbance
- Any proposed SSRS is effective.

6.4.3 Assessment outcome

Transgrid will consult with AEMO on the outcomes of the SSA and any proposed SSRS.

If adverse impacts are identified, Transgrid will work with you to identify potential solutions. All issues must generally be resolved before the 5.3.4A letter is issued, although the letter may include conditions where specific issues may be resolved prior to Registration.

If the wide area network assessments identify new or changed network or plant dispatch limits, further detailed limit assessments will be required before Registration. This may result in Transgrid providing AEMO with new or revised limit advice to update the relevant constraint equations prior to Registration.

Note: under the open access framework, limit advice may continue to be refined as the network evolves, including to account for newly committed generation and network augmentations. This may result in AEMO revising constraint equations over time, which may affect your plant.

6.5 Approval of Performance Standards

Once Transgrid and AEMO are satisfied that due diligence issues have been adequately addressed, the proposed NAS are acceptable and the SSA is complete, Transgrid will confirm the final proposed performance standards with you.

Transgrid will then formally endorse the GPS to AEMO and seek AEMO's response under NER 5.3.4A and, where applicable, under NER 5.3.4B.

Following AEMO's response, Transgrid will formally accept the performance standards. Any outstanding matters will be documented in the project tracker and, where applicable, included as conditions in AEMO's 5.3.4A response and/or Transgrid's acceptance letter.

6.6 Validity of Assessment

AEMO's 5.3.4A response is valid for a period of 12 months from the date of issue, provided the assessed information does not change. If you do not enter into a Connection Agreement within that period, contact Transgrid for further advice.

6.6.1 Inability to meet performance standards due to changes

Changes to the proposed connection may impact your plant's ability to meet the agreed performance standards, potentially requiring an alteration assessment. Changes to the network – including newly committed projects – may present similar challenges. You may need to retune or coordinate plant control system settings, modify or add ancillary plant, or other measures to meet or negotiate appropriate performance standards.

6.6.2 Circumstances requiring a system strength re-assessment

If any other projects in the same area of impact for system strength become 'committed' before the proposed connection, Transgrid is required to repeat the full System Strength Assessment and consult with AEMO. Changes to the proposed connection may also require a repeat of the System Strength Assessment. You must remediate any adverse system strength impacts identified during the re-assessment before the Network Connection Agreement can be executed.

To help identify reassessment requirements early, consult with Transgrid at least 8-10 weeks before the expected execution of the Network Connection Agreement or any 5.3.4A extension requests. The scope of the re-assessment will be limited and determined based on the extent of the relevant changes.

Chapter 7

Offer to connect

Once performance standards are approved and connection agreements negotiated, your Commercial Proposal Manager will issue an Offer to Connect.

If you wish to accept the offer to connect, execute the connection agreements (below) within the stated timeframe.

- The Network Connection Agreement will incorporate the agreed performance standards for each applicable technical requirement under Schedule 5.2, as well as the ongoing technical, commercial, operational and compliance obligations applying to the connection.
- The Project Agreement sets out the works that Transgrid will undertake to enable the connection.

Following execution of the Network Connection Agreement, you and Transgrid must jointly notify AEMO that a Network Connection Agreement has been executed in accordance with NER clause 5.3.7(g).

Once this stage is completed, the proposed connection will be considered as a committed plant in the NEM.

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