



**QNI UPGRADE PROJECT UPDATED
TEST PROGRAM FOR INTER-NETWORK TESTS**

QNI Upgrade – Inter-network Test Program Document

Version Release History

VERSION	DATE	BY	REVIEWED	CHANGES
0.1 - Draft	13/5/2021	QNI Test Working Group	QNI Test Working Group	Version for consultation with the Jurisdictional Planning representatives under clause 5.7.7 (m) of the NER
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Important Notice

Purpose

This document has been prepared by Transgrid and Powerlink in consultation with AEMO, and determined by AEMO as the inter-network test program for the QNI Upgrade as required by clause 5.7.7(q) of the National Electricity Rules (Rules) following consultation with interested Registered Participants. This document has effect only for the purposes set out in the Rules. The Rules and the National Electricity Law (Law) prevail over this document to the extent of any inconsistency.

Disclaimer

This document might also contain information which is provided for explanatory purposes. That information does not constitute legal or business advice, and should not be relied on as a substitute for obtaining detailed advice about the Law, the Rules, or any other applicable laws, procedures or policies. AEMO, Transgrid and Powerlink have made every effort to ensure the quality of the information but cannot guarantee its accuracy or completeness.

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1. SCOPE AND CONSULTATION

This inter-network test program document for the upgrade of the Queensland to New South Wales Interconnector (QNI) is published in accordance with the requirements of clause 5.7.7(q) of the National Electricity Rules (Rules), which deals with inter-network tests.

The inter-network test program does not cover plant commissioning tests and other network tests that may be required in making the new transmission works fit for service.

The QNI Upgrade Project will increase the power transfer capability between NSW and Queensland by more than 3% and hence is anticipated to have a material inter-network impact (MINI)¹. In addition, new Static Var Compensators (SVCs) are to be commissioned and modifications made to SVC control systems. In accordance with clause 5.7.7 and the Inter-network Test Initiation Guidelines², AEMO has determined that inter-network tests are required.

It should be noted that technical studies are underway to refine various aspects of this test plan. These studies include:

- Establishing the need for commissioning Power Oscillation Dampers (PODs) on the existing and new SVCs.
- Determination of the limit equations that will define the secure power transfer capability of QNI.

As such, some of the technical details in this plan will be modified up until the commencement of the inter-network tests.

AEMO published the draft inter-network test plan document in January 2021 and sought feedback from Registered Participants. AEMO received one submission (from CS Energy) during the consultation, AEMO has updated the inter-network test plan document to address the questions raised in the submission. In addition, AEMO's response to the submission can be found on the consultation website³.

2. INTERCONNECTOR UPGRADE BACKGROUND

QNI connects the northern NSW system at Armidale to the southern Queensland system at Bulli Creek. The interconnection comprises a double circuit 330kV line from Armidale to Bulli Creek via Dumaresq with supporting switchyards, voltage control plant and secondary systems.

The QNI power transfer is defined as the summated power flow across the two 330kV lines between Dumaresq in New South Wales and Bulli Creek in Queensland.

Existing Capability

The existing QNI nominal capacity is summarised in the table below.

¹ See https://aemo.com.au/-/media/files/electricity/nem/network_connections/transmission-and-distribution/170-0035-pdf.pdf

² See https://aemo.com.au/-/media/files/electricity/nem/network_connections/170-0061-pdf.pdf

³ See <https://aemo.com.au/consultations/current-and-closed-consultations/qld-to-nsw-interconnector-qni-upgrade>

Table 2.1 - Existing QNI capability

From	To	MW Capability	Constraints
NSW	Queensland	300-600	<p>Voltage control⁴ on loss of the largest Queensland generating unit.</p> <p>Voltage control for a trip of the Liddell to Muswellbrook 330kV transmission line.</p> <p>Transient stability for a trip of the Kogan Creek generator or a Tarong North generator.</p> <p>Transient stability for a trip of the Liddell – Muswellbrook 330kV line or the Liddell – Tamworth 330kV line.</p>
Queensland	NSW	1200	<p>Voltage control for a trip of the 330kV line between the Sapphire Wind Farm and Armidale.</p> <p>Transient stability limits for a fault on either a Bulli Creek to Dumaresq 330kV circuit⁵ or the Armidale to Dumaresq 330kV line.</p> <p>Transient stability limits for a trip of a smelter potline in central Queensland.</p> <p>Transient stability limits for a fault in the Hunter Valley and trip of a 330kV line.</p> <p>Thermal capacity of the 330kV transmission network between Armidale and Liddell in NSW.</p> <p>Oscillatory stability. The existing oscillatory stability limit relies on the availability of the on-line oscillatory damping monitoring within the AEMO control rooms.</p>

Upgraded capability

The QNI upgrade works are shown in Figure 1.

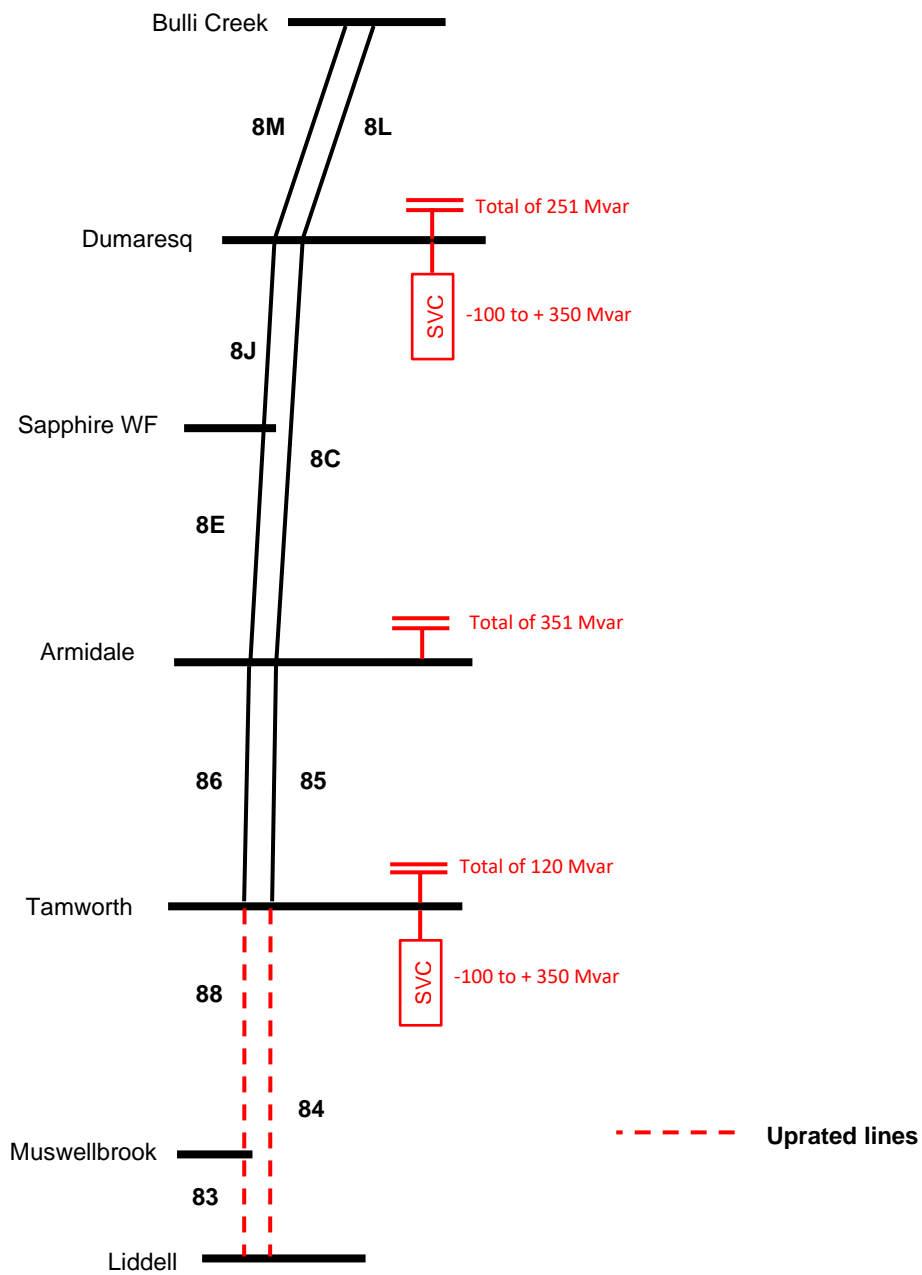
The QNI upgrade also includes work on the secondary systems (communications, control and protection) in both the NSW and Queensland systems.

⁴ The term “voltage control” in this document is intended to cover the maintenance of adequate voltage levels as well as voltage stability.

⁵ In this document reference will be made to each “circuit” where a double circuit line is made up of two circuits between two switchyards. Otherwise reference will be made to a “line” where there is only one circuit between two switchyards.

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Figure 1 - Overall QNI upgrade works



With the QNI upgrade works completed the power transfer limits are expected to be modified as summarised below.

Table 2.2 – Upgraded QNI capability

From	To	MW Capability	Constraint ⁶
NSW	Qld	up to 950MW	<p>The limit will be determined by line ratings, voltage control and transient stability.</p> <p>The transient stability and voltage control limits are dominated by a trip of the fully-loaded Kogan Creek generating unit.</p> <p>The thermal limit occurs for outage of the Liddell – Tamworth 330kV line and is governed by the rating of the Liddell – Muswellbrook 330kV line.</p> <p>The ratings of the 330kV lines immediately north of the New England Solar Farm may also impose thermal limits.</p>
Qld	NSW	up to 1450 (during winter conditions)	<p>The limitation is likely to become the thermal rating of one of the Bulli Creek - Dumaresq 330kV circuits, Armidale to Tamworth 330kV line or the Dumaresq – Armidale 330kV line. The highest increases occur at times of high NSW demand and low output from renewable generation in northern NSW.</p> <p>Transient or voltage stability limits are not likely to constrain during system normal conditions.</p> <p>Oscillatory stability. The oscillatory stability limit is expected to generally be greater than the other limits. It will rely on the availability of the on-line oscillatory damping monitoring within the AEMO control rooms.</p>

Transgrid is responsible for the transmission works in NSW and Powerlink for the works in Queensland. The QNI upgrade works comprise the following major items of line upgrading and new reactive plant installation.

Upgrading of 330kV transmission lines in NSW to a design temperature of 120°C:

- Liddell – Muswellbrook No.83
- Liddell – Tamworth No.84
- Muswellbrook – Tamworth No.88

Static Var Compensators (SVCs) (and associated switchgear):

- Tamworth: -100 to +350Mvar at nominal voltage
- Dumaresq: -100 to +350Mvar at nominal voltage

Switched shunt capacitors (and associated switchgear):

- Tamworth: 2 x 60Mvar - total of 120Mvar, at nominal voltage
- Armidale: 2 x 50Mvar and 2 x 125.5Mvar - total of 351Mvar, at nominal voltage
- Dumaresq: 2 x 125.5Mvar - total of 251Mvar, at nominal voltage

⁶ The details of the limiting constraints are subject to further analysis.

The new dynamic reactive devices will be fitted with the capability to implement Power Oscillation Dampers (PODs) and the existing Armidale SVC POD is available for setting and commissioning.

Power system analysis is underway to determine the need for commissioning of the PODs on the existing Armidale SVC and the new SVCs at Tamworth and Dumaresq. If the PODs are commissioned to assist system damping they will also be tested as part of the inter-network tests. Details of these tests are included in this document for completeness. The need or otherwise to set and commission these PODs will be finalised as part of the preparatory power system analysis.

Transgrid and Powerlink are joint proponents of the upgrade to increase the power transfer capability.

Transgrid and Powerlink aim to achieve full commercial service of the QNI upgrade by mid-2023⁷.

Inter-network testing is aimed to be commenced in June/July 2022. The final dates for the commencement of tests will be advised to participants via market notices.

3. REQUIREMENTS OF THE RULES ADDRESSED IN THIS TEST PROGRAM

Transgrid, Powerlink and AEMO have jointly coordinated the development of the test program. AEMO in its capacity as system operator of the National Electricity Market, and the proponents identified that inter-network testing is required for the QNI upgrade in accordance with clause 5.7.7(g) of the Rules.

Draft versions of this test program underwent consultation with the Jurisdictional Planning Representatives in accordance with clause 5.7.7(f) and (m), and with interested Registered Participants under clause 5.7.7(p). This final test document is published in accordance with clause 5.7.7(q).

Power system analysis is underway to confirm technical details of the tests and section 16 of this document, covering the Test Procedure may be progressively updated, particularly as the tests proceed. AEMO and the proponents are also further investigating the monitoring equipment required for the tests (as set out in Appendix C) and these details will also be progressively updated.

4. NEED FOR INTER-NETWORK TESTS

Inter-network tests for the QNI upgrade are intended to measure the impact on system damping and ensure that the operation of transmission and generator plant control systems are coordinated.

The system damping tests are required to:

- Quantify the impact of the upgrade and the resulting change in power transfer across QNI on damping of modes of oscillation within and between all NEM regional networks for the full range of power transfer on the upgraded interconnector.
- Verify that the damping of all modes of oscillation meets specified Rule requirements. It is necessary to ensure that any oscillations will adequately damp out over time and not be sustained at a high level or allowed to grow.
- Validate the system model (covering the existing system and new plant) at the increased interconnector transfer in both directions as afforded by the QNI works upgrade.

The control interaction tests are required to:

- Ensure that there is adequate co-ordination between the control systems of the new power system plant and those of the existing plant at the increased interconnector transfer in both directions as afforded by the QNI works upgrade. This includes the operation of the power system controls on existing generators.

⁷ Depends on the availability of favourable test conditions.

The QNI upgrade is to be considered to be developed in a single stage and the inter-network tests will be able to commence when the transmission works have been completed, commissioned and available for service.

5. COMPLIANCE WITH CLAUSE 5.7.7 OF THE RULES

Clause 5.7.7(r) of the Rules states that in determining the test program, AEMO must so far as practicable have regard to the following four principles:

1. Power system security must be maintained in accordance with Chapter 4 of the Rules.
2. The variation from the central dispatch outcomes that would otherwise occur if there was no inter-network test should be minimised.
3. The duration of the tests should be as short as possible consistent with test requirements and power system security, and
4. The test facilitation costs to be borne by the proponent should be minimised.

Principle 1

At all times, AEMO will have sole management of power system security, and no variation to the requirements of Chapter 4 of the Rules are required by these tests.

Principle 2

System conditions for conduct of the tests will be achieved through normal market dispatch and, therefore, does not represent a distortion of market outcomes. Suitable test conditions will include an expectation of minimal disruption to normal market and system outcomes. Tests that disturb the system are planned to be completed within a single trading interval and in such a way that there is minimal impact on any of the dispatch processes (including pricing and negative settlement residue processes). Although AEMO does not anticipate these tests impacting dispatch processes, if there is an impact AEMO will follow normal procedures. The tests may be scheduled to coincide with particular loading and interconnector transfer conditions that appear in pre-dispatch. However no action, other than waiting for more favourable opportunities, is intended to secure particular test conditions.

Principle 3

The main determinant of the time required for a test is the duration of data acquisition needed to characterise the frequency and damping of oscillation modes. Experience from previous tests has established minimum testing times that will give satisfactory results and are relatively immune to the influence of market variations. There is no trade-off required between the test period and system security, because the latter is continuously managed by AEMO to the same standard, whether or not there is a test in progress.

Principle 4

This Test Program does not envisage it will be necessary for AEMO to acquire Test Facilitation Services (as contemplated by the clause 5.7.7(ac)) to establish conditions necessary for the Inter-network Tests (refer section 11 of this document).

6. TEST METHODOLOGY

6.1 Pre-test Modelling, Monitoring and Benchmarking

The inter-network test methodology is based upon pre-test modelling and analysis of the system capability and behaviour.

The following set of activities will be undertaken in advance of the inter-network tests:

- Models of the network and the connected generators will be updated by AEMO and the TNSPs to accurately reflect the state of the power system that will apply at the time of the tests.

- The expected damping behaviour of the system will be analysed using software that is used by AEMO and the TNSPs.
- The capability of the power system to transfer power will be quantified and expressed as limit equations. These equations will undergo the usual due diligence process undertaken by AEMO and entered into the market dispatch systems.
- The behaviour of the system in response to any proposed system disturbances will be modelled and analysed.
- Critical contingencies, under the conditions that will apply during the tests, will be analysed to ensure the ongoing security of the system.
- Augmentations to plant control systems, including the PODs on SVCs, will be designed and modelled, those models will be tested and the settings will be subjected to an AEMO review process.

The modelled damping behaviour of the system has previously been benchmarked against actual system recordings and acceptable alignment reached by modifications to a selected set of plant stabiliser models.

6.2 Test Conditions

Damping tests will involve continuous monitoring of system damping over a nominated range of system conditions and individual tests to impose disturbances to the system.

Test conditions are to be defined in terms of key system variables that affect system damping. Some may include:

- A range of demands and synchronous machine dispatch patterns across the NEM.
- Power transfer from Queensland to New South Wales via QNI over the full range of the upgraded capability.
- Power transfer from New South Wales to Queensland via QNI over the full range of the upgraded capability.
- Power transfer over Directlink.
- Power transfer to South Australia over the full range of the combined Heywood and Murraylink interconnector capability.
- High and low Sapphire Wind Farm output.

It is expected that the required system conditions will be delivered by the normal operation of the NEM and normal market conditions.

Test facilitation services may be utilised if the required power transfer conditions are not obtained within a reasonable time (refer section 11). Test facilitation services include the out-of-merit operation of generators and if necessary would involve contracts between the QNI upgrade proponents and the service provider. Such test facilitation services can involve a considerable cost and it is aimed to avoid extra costs where practicable.

Existing frequency control ancillary services will be applied. It is not intended that any additional services would be procured for the tests. Tests are to be carried out at a series of hold points defined by fixed limits to power transfer over the QNI and Directlink interconnectors.

The full constraint set is to be applied in addition to the fixed transfer limits at all times during the tests. At times the full constraint set will undercut the fixed limits, subject to system generation and loading conditions.

The majority of inter-network tests will be carried out under transmission system normal conditions. In addition, power system performance will be monitored throughout the test period. Tests may be conducted during planned outages of major transmission plant where system damping is considered to be affected. This may include outages of SVCs and major transmission lines. AEMO, Transgrid and Powerlink will identify any planned outages for which tests are to be conducted. It is not intended to arrange transmission plant outages for the purpose of conducting inter-network tests where this would reduce transfer capability or otherwise impact adversely on the market.

The range of tests will include the following:

- Generic system damping tests.
- Disturbances to the system operating point.
- Monitoring naturally occurring disturbances.
- Control system co-ordination tests.

6.3 Generic System Damping Tests

The majority of system damping tests will utilise the continuous system perturbations caused by small, natural variations in system load and generation. No deliberate switching of transmission lines or other plant will be required for these tests. The cost of performing the tests and the impact on system security and the market is therefore minimised.

A generic system damping test at a nominated hold point will involve the following steps:

- Pre-test simulations of the expected damping performance for the proposed test conditions using the University of Adelaide's Mudpack program, which is presently the standard modelling and software package used by AEMO and TNSPs.
- Raising of the constraint on the maximum QNI transfer within the National Electricity Market Dispatch Engine (NEMDE) to the hold point level required for the test.
- Continuous security monitoring by AEMO.
- Allowing the market to deliver the required transfer over QNI and other interconnectors, to be specified in the detailed test procedures.
- Observation and monitoring of system damping until the required range of system conditions is obtained - a period of at least 24 hours is anticipated for each test (which includes at least 3 hours of monitoring).
- Cessation of test operation at the fixed transfer level required for the test and market operation within secure constraints.
- Offline test analysis by identification of changes in damping that occurred during the test period, compared with changes indicated by simulation of the actual test conditions.

At the conclusion of each test and based on results of the offline test analysis and hold point reports by Powerlink and Transgrid, the AEMO-appointed Test Co-ordinator (refer section 8) shall advise whether:

- Adequate data are available to identify the level of damping at the test level;
- Damping observed during the test was within the expected range; and
- A test at a higher transfer level may be scheduled, subject to AEMO's management of system security.

It may be necessary to repeat tests at a particular hold point if additional damping evidence is required or revert to a prior hold point if unexpected performance is observed.

Two flowcharts in Appendix A illustrate the process for conducting the tests:

- The flowchart of Figure 2 shows the process for progressing between test hold points.
- The flowchart of Figure 3 shows the process for reviewing and assessing the test results.

6.4 Test Disturbances Imposed on the System

The system operating point will be deliberately disturbed to excite system oscillations and to measure their decay. Various tests will be conducted at certain hold points (see Section 16). The types of disturbances include the switching of transmission lines and step changes to voltage control reference points at selected generators and SVCs that have a voltage control function.

Preliminary system studies have indicated that:

- Voltage reference steps applied to the Dumaresq and Armidale SVCs are the most effective at exciting the QNI inter-area mode of oscillation. The magnitude of the oscillations excited by these tests may however not be large enough to provide information on the system damping

performance. The impact of a voltage reference step change to generators was found to be less pronounced than for a voltage step on the SVCs.

- Line switching and generator tripping tests are effective at exciting larger oscillations. The critical lines are along the Armidale – Dumaresq – Bulli Creek corridor. However, these tests carry a higher level of risk particularly at high QNI transfer levels.
- The system response pre and post the QNI upgrade is observed to be different for the same QNI transfer level. This fact could be used to undertake tests at lower transfer levels with reduced risk for model validation purposes.

To manage the risk to the system of the switching of 330kV lines along the Armidale – Dumaresq – Bulli Creek corridor the duration of a line outage would be limited to 60 seconds. Whilst 60 seconds will not allow the quantification of the actual damping levels of system oscillatory modes it will indicate that transients have adequately decayed. The line tripping and reclose could be arranged in two ways:

- Extending the auto-reclose timer on a line to about 60 seconds and then initiating a line trip followed by the automatic reclose. The switching process would be initiated from a substation control room using on-site staff. It is expected that the initial transients would die out over some seconds leaving 40 seconds or more to observe the occurrence of any underlying sustained oscillations.
- Initiating a trip and reclose manually with an appropriate delay of about 60 seconds from a network control room.

The first approach is considered to have a lower risk than the second. However, the test would require specialist protection staff on-site at the substation control room to arrange the auto-reclose sequence timing and they would then be available to exercise direct control over circuit breakers to restore a line to service should this be required.

There are effectively two parallel AC circuits connecting NSW and Queensland. With one of these effectively out of service for the 60 seconds duration of a test there is a risk should the second circuit fail. Hence line switching tests will only be performed at QNI transfers where it is determined that there is acceptable risk to the system and continuity of supply, which includes consideration of the level of frequency control ancillary services available or dispatched through the market at the time.

Whilst generator tripping can excite relatively large oscillations the cost of such tests could be high and there is a risk to system security. There is no apparent advantage over line switching tests and hence generator tripping tests are not included in the set of QNI tests.

The disturbance tests described below will be carried out.

Line Switching Tests

These Line Switching Tests will be carried out within a single trading interval. As such the line will trip and be reinstated before any relevant network separation constraints are required. This approach is consistent with existing practices for “in service protection auto-reclose checks”.

Each test will comprise:

- A selected 330kV line between Armidale, Sapphire, Dumaresq and Bulli Creek will be tripped and the system response recorded.
- The line will be switched back into service after 60 seconds and again the system response will be recorded.

It is expected that system transients will die out over some seconds following the line switching and there will be adequate time to then identify any sustained system oscillations.

SVC Voltage Reference Step Tests

Each test would comprise:

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- A 5% step is applied to the Armidale, Tamworth and Dumaresq SVCs reference points in turn.
- After 60 seconds the voltage set point is returned to normal.

Both the imposition of the voltage change and the restoration of the voltage to the normal pre-test level will initiate a system response which will be recorded.

6.5 Monitoring of Naturally Occurring Disturbances

Large-scale disturbances to the operating conditions of the system occur due to natural events which may be caused for example by the tripping of lines or plant.

Existing monitoring equipment records naturally occurring disturbances on the power system. Various high-speed and slow-speed recording devices are also in service at locations across the NEM.

Records of such disturbances can be useful in identifying system damping as well as non-linear or “large signal” system responses. Records of any natural system disturbances occurring during the inter-network test program will be reviewed and if considered valuable, included as test evidence to verify system dynamic performance and to validate the simulation model.

6.6 Control System Coordination Tests

The control systems on transmission plant and on generators in the NEM are coordinated to ensure that they respond appropriately to system disturbances. At selected hold points, tests may be conducted to identify any lack of coordination between plant and system controls.

It is intended to introduce disturbances to the system to effect particular responses from control systems. The following tests are proposed:

- Switch a critical line out of service and after a delay switch it back in.
- Apply a step voltage change to a selected SVC reference voltage.
- Apply a step voltage change to the Sapphire Wind Farm generator control.

Both HSM and OSM measurements (see Section 13) will be required.

6.7 Test Structure

Depending on the outcomes of present studies, the SVC PODs may be commissioned to assist with system damping. The PODs would be tested individually and once proven to be effective turned on sequentially.

The structure of the inter-network and SVC tests is as follows.

Table 6.1 - Structure of the tests

Interconnector power transfer MW – in both directions	Type of test	Status of SVC PODs	Comments
Less than or at the existing limits	<ul style="list-style-type: none"> • Continuous monitoring • SVC voltage reference step change • Line switching tests 	<p>If the PODs are required to be commissioned –</p> <p>The PODs are tested individually.</p> <p>They are each enabled for 3 hours, recordings are taken, and then the POD is disabled.</p>	<p>This will confirm the modelling used to determine the POD settings and also confirm the effectiveness of the SVC PODs, if it is decided that they need to be commissioned.</p>

Interconnector power transfer MW – in both directions	Type of test	Status of SVC PODs	Comments
At the existing limit	<ul style="list-style-type: none"> • Continuous monitoring • SVC voltage reference step change • Line switching tests 	<p>If the PODs are required to be commissioned –</p> <p>The PODs are tested individually.</p> <p>They are each enabled for 3 hours, recordings are taken, and then the POD is disabled</p> <p>When all of the PODs are proven they are then enabled sequentially.</p> <p>A further set of tests with all of the PODs enabled will be undertaken</p>	<p>This sets a reference point for damping measurements enabling progressing to higher power transfers.</p> <p>Control interactions will also be assessed.</p>
At the existing limit	<ul style="list-style-type: none"> • Voltage reference step change applied to the Sapphire Wind Farm 	PODs enabled (if they are required to be commissioned)	Specific control interaction test
Increase the limit in 50MW increments (or greater, subject to criteria defined in section 16.5 being met) above the existing limit until the maximum capability is reached.	<ul style="list-style-type: none"> • Continuous monitoring • SVC voltage reference step change • Line switching tests (see Note below) 	PODs enabled (if they are required to be commissioned)	<p>The tests at the various hold points confirm the capability of the interconnector works.</p> <p>Control interactions will also be assessed.</p>
At the maximum power transfer	<ul style="list-style-type: none"> • Voltage reference step change to the Sapphire Wind Farm 	PODs enabled (if they are required to be commissioned)	Specific control interaction test

Note: Subject to further considerations of system security the line switching tests may only need to be conducted at less than maximum power transfers.

7. PROPOSED TIMING OF THE TESTS

Before commencing the Inter-network Tests, the QNI upgrade plant and facilities will be commissioned by Transgrid and Powerlink.

Commissioning under the relevant agreements for those works will include functional checks of all associated protection systems and communication systems.

AEMO will monitor the switching operations performed as part of the plant commissioning tests. Recordings will be analysed where considered appropriate to provide useful information about system damping.

The Inter-network Tests will start when the new plant is made available for normal service and pre-commissioning checks have been completed. The tests are expected to begin in June/July 2022 and be complete by mid-2023. It is possible that tests will be mainly carried out over the summer months and the 2022 winter months. The final testing dates will be advised to participants via market notices.

High demand and peak interconnector flows are most likely to be delivered by the market during the January - February summer months.

7.1 Indicative Timing for the Release of Capacity

The capacity of QNI will be progressively released to the market once the testing at each hold point has been completed, the results analysed and the assessment criteria set out in this document have been satisfied.

At this stage indicative timings for the release of capacity are as follows:

- 50% of the increase in capacity - December 2022⁸.
- The full increase in capacity by mid-2023 (conditional upon the upgrade of secondary systems plant in northern NSW).

These timings will be updated at the time when the tests commence and progressively throughout the test program.

8. MANAGEMENT OF POWER SYSTEM SECURITY DURING THE TESTS

AEMO will exercise its normal responsibility for power system security throughout the test program and must be satisfied that the power system meets the security requirements specified in Chapter 4 of the Rules at all times. AEMO will manage security mainly by observing constraints that are included in the dispatch engine NEMDE.

The security risks are further mitigated by the following:

- Each test will be supported by simulations that will cover worst-case credible contingency events. Tests will not proceed if the predicted performance is outside of specified Rules requirements.
- AEMO, Transgrid and Powerlink will confirm they are satisfied on the basis of simulations that the proposed test conditions lie within the secure technical envelope.
- AEMO will receive alarms from Psymetrix if system damping is outside acceptable levels⁹. In this case tests may need to be cancelled and interconnector transfers reduced.
- Transgrid and Powerlink will monitor system responses in real time during any plant switching for the purpose of plant coordination tests. If measured responses are outside of Rules stability requirements or not as anticipated, the test will be cancelled and AEMO may reduce the interconnector transfer to a secure level.
- At all times during the tests, the proponents' and major plant contractors' technical staff will be available to provide remedial action if required.

⁸ Depends on the availability of favourable test conditions and results.

⁹ Similarly, for Psymetrix outages inter-connector constraints are invoked.

Under clause 5.7.7(ad) an Inter-network Test must be coordinated by an AEMO-nominated officer (Test Co-ordinator) with authority to stop the test or any part of it, or vary the procedure within pre-approved guidelines determined by AEMO if that officer considers them necessary. The guidelines determined by AEMO for taking these actions are outlined in section 12.

There is no need for special contingency arrangements as all tests will be carried out under secure system conditions applicable to the future commercial operation of the NSW to Queensland interconnection. The normal security-constrained dispatch provided by NEMDE will ensure sufficient reserve to cater for reduced flow between NSW and Queensland to within constraints applying before the upgrade.

9. OPERATING AND TESTING STAFF DEPLOYMENT FOR THE TESTS

The management of the tests will involve the coordination of the AEMO System Operators and the Transgrid and Powerlink Network Controllers.

AEMO will utilise staff in its control rooms and Transgrid and Powerlink will utilise staff in the network control rooms at Wallgrove and Brisbane respectively.

The Test Co-ordinator will be located remotely, but will be in direct contact with control room staff and the test team.

Line switching will generally be undertaken from the various control rooms. Line switching tests will require protection technician staff to be on-site at the relevant substations, if in AEMO's view a delay in the return to service would lead to an LOR2 condition.

All of the analysis of the tests will be undertaken in the AEMO, Transgrid and Powerlink centres.

10. PRE-CONDITIONS BEFORE COMMENCEMENT OF THE SYSTEM TESTING PROGRAM

Before the commencement of the inter-network tests at the hold points set out in Section 16.2, all of the new plant and associated secondary systems will have been commissioned and functionality tests completed. The new plant will therefore be considered fit for purpose.

In addition the following requirements must be met:

- All models have been validated and demonstrated as fit for purpose for use in power system simulation software (e.g. PSS/E, PSCAD and MUDPACK).
- All new control system settings (e.g. SVC POD settings if demonstrated to be required) have been reviewed and accepted by AEMO.
- All new equipment (e.g. SVCs) have been fully commissioned, and the test results reviewed and accepted by AEMO. Should the POD's be required to be commissioned, their testing would form part of the inter-network tests under this test plan.
- (Minimum) R1 models for the new plant have been accepted by AEMO in accordance with the Rules.

11. REQUIRED POWER SYSTEM CONDITIONS FOR CONDUCTING A TEST

System damping tests will require relatively constant system conditions over several hours, and hence will avoid the morning run-up and peak, the evening peak, and any nightly hot water peak. Indicative test periods are 9am to 5pm, and midnight to 7am on most days.

Switching out or in of critical interconnecting lines for substantial periods during the test may invalidate results and cause a need to repeat or extend the test interval. Critical lines are those that have an impact on system damping, and will be identified by Transgrid and Powerlink through power system analysis. Having a line switched out for the full duration of a test has no impact, provided the test conditions can be obtained in a secure manner.

System conditions for conducting a system damping test will generally require total power transfer in a specified direction between NSW and Queensland. This will be achieved through normal market dispatch. The tests may be scheduled to coincide with particular loading and interconnector transfer

conditions that appear in pre-dispatch. No action, other than waiting for more favourable opportunities, is intended to obtain these conditions.

This test program does not identify any requirement for engaging Test Facilitation Services. However, clause 5.7.7(u) of the Rules provides that:

- 5.7.7.(u) The proponent in respect of an inter-network test must seek to enter into agreements with other Registered Participants to provide the test facilitation services identified in the test program in order to ensure that the power system conditions required by the test program are achieved.

AEMO, Transgrid and Powerlink expect that the range of system conditions required to complete the tests will be delivered by the Market. However, should the critical range of required conditions not be obtained within a reasonable period of time, Transgrid and Powerlink may seek to obtain test facilitation services which could be utilised by AEMO in order to complete the tests.

If test facilitation services are procured the test program will be updated accordingly.

12. GUIDELINES AND DECISION MAKING FOR CONTINUING OR CONCLUDING A PARTICULAR TEST

A test will be scheduled on the basis of:

- NEMDE pre-dispatch indicating:
 - Ability to achieve the required interconnector transfer in the specified direction within security constraints.
 - Regional demands and transfers on other interconnectors are consistent with the test scope.
 - No planned switching of critical interconnecting lines during the period.
- Availability for service of all apparatus necessary for monitoring test outcomes being confirmed.

The guidelines given by AEMO to the Test Co-ordinator are summarised below.

Under clause 5.7.7(ad), the Test Co-ordinator may stop, suspend, reschedule or abandon the test or any part of it or vary the procedure in the event that:

- There is a predicted inability to maintain secure dispatch at the test transfer level.
- The on-line damping monitoring systems become unavailable.
- There is a problem with any installation of damping monitoring equipment or damping analysis software that could prevent analysis of results or invalidate the test.
- The on-line damping monitor shows low damping, and AEMO has the reasonable opinion that this can be best corrected by reducing the power transfer between Queensland and NSW.
- There is a necessity to vary test procedures or redesign the test to ensure that relevant conclusions and recommendations may be drawn from the test results.
- Extra analysis or review (in consultation with the relevant TNSPs or AEMO) is required.
- A contingency disturbs the expected constancy of system conditions or any other changes in system conditions occur that may invalidate test data.
- An unplanned outage of a critical line, synchronous condenser, Statcom or SVC occurs that is not restored to normal within 10 minutes.
- There is a problem with any transmission plant.
- AEMO identifies any other reasonable grounds to stop the test consistent with its obligations under the Rules.

Except in urgent circumstances, the Test Co-ordinator will consult with relevant test team members who could inform the decision (including AEMO, Transgrid and Powerlink).

AEMO will implement any constraint required to maintain security when a decision is made in accordance with the above guidelines.

13. TEST ANALYSIS

13.1 Measuring the Power System Response

The power system response will be monitored using existing, permanently-installed measuring equipment at a number of locations. It is possible that this range of equipment will be supplemented with additional equipment prior to the tests. This equipment will record all system data required for the Inter-network tests. It includes the following:

- **Oscillatory System Monitor (OSM)** – The OSM consists of phasor measurement units (PMUs) located near load centres in the four mainland regions. The PMUs record voltage magnitude and relative angle in each region referred to a common GPS time signal. The OSM includes two software tools for calculating and recording the damping and frequency of major system oscillatory modes derived from PMU measurements.
 - Psymetrix PhasorPoint real-time oscillatory stability tool – continuously displays an historic record of measured damping in AEMO’s control centres. This on-line tool calculates damping of dominant system oscillation modes from voltage phasor measurements averaged over several minutes. It will be used for system security assessment during test periods.
 - Modal identification algorithm developed by Queensland University of Technology (QUT) and Transgrid – calculates system modal damping from PMU measurements over a longer period. This off-line tool has been benchmarked for accuracy and nominated by AEMO to assess damping in accordance with Schedule S5.1.8 of the Rules including, if required, applying constraints (based on TNSP limit advice) to ensure that the criterion for “adequate damping” in the Rules is satisfied.
- **High Speed Monitors (HSMs)** – The HSMs record continuous RMS data at 50 samples per second plus triggered waveform data. HSM data will be used to assess time domain system responses to intentional large-scale disturbances to the system and naturally occurring disturbances. Triggered waveform data will be used to check for evidence of uncoordinated actions of plant controllers.

13.2 Analysis of Test Results

At each testing stage, Transgrid and Powerlink will assess the measured levels of damping and compare these with computer-based damping analysis applied to system load flow “snapshots” from AEMO’s Operational Data Management System (OPDMS). These comparisons will be used to:

- Determine whether system damping performance is consistent with that predicted by the system model, and hence whether analytical results can be extrapolated to less favourable system conditions that are not tested (including post-contingency damping).
- Where necessary, develop or refine procedures to adjust simulation parameters or simulation output to improve representation of actual system damping.
- Provide outcomes and advice to the test facilitation officer.

Any significant differences between the simulated and measured responses should be explainable through analysis of the power system model. Inexplicable results may lead to a need to repeat tests, vary the test procedure or necessitate a delay to the test program while the discrepancy is investigated.

14. IMPACT ON PARTICIPANTS’ PLANT

14.1 Generic System Damping Tests

The equipment used to measure power system damping measures the inherent damping of the power system without need for specific disturbances to be applied. Hence, during the majority of the test period there will be no visible or material impact on participants’ plant connected to the grid.

14.2 Intentional Large-Scale Disturbances

The disturbances caused by deliberate switching of transmission lines or voltage step changes to plant control systems will be no greater than the disturbances that occur from routine switching of local transmission lines or the switching of transmission lines due to transmission line protection actions.

15. COMMUNICATION WITH PARTICIPANTS

This test program will be placed on the AEMO website in accordance with clause 3.13.13. Tests described in this program may only start after 20 business days from publication.

Market Notices will be issued giving notice of the intended commissioning of the QNI upgrade works and the intended start of the inter-network tests.

During active testing, a Market Notice and/or communication will be issued to advise when a series of tests will be conducted. As dispatch for testing will be achieved through the market systems, the market impact of the scheduled test will be evident to market participants through pre-dispatch and dispatch schedules.

If it is necessary to vary a test procedure, in a manner that AEMO reasonably considers does not differ materially from that stated in this Program, AEMO will advise the market of the reason for the change through established communications.

At the end of testing at each test hold point, a test report will be provided by Transgrid and Powerlink, and a final Market Notice will be issued by AEMO to advise when the increased capability of QNI (as defined by the hold point) ceases to be subject to Inter-network test conditions and is released to the Market. This step is at AEMO's discretion, and will follow consideration by AEMO of a report on the results of all damping measurements and disturbance tests for that hold point.

16. TEST PROCEDURE

This section sets out the procedure for carrying out the tests. If pre-requisite power system analysis determines the need for PODs then the SVC PODs will be tested first. Once the PODs are proven they will be enabled and then tests will be undertaken at progressively higher power transfers in both flow directions over QNI. The timing of the tests will be governed by opportunities arising from market driven power transfers over QNI.

The structure of this section is as follows:

16.1 - A summary of the schedule of tests.

16.2 - Pre-requisites for conducting the tests.

16.3 - Base-line tests at or below the current limits once the QNI works are in-service. The Tamworth, Armidale and Dumaresq SVC PODs are not enabled.

16.3.1 - QNI Export and Import tests.

16.4 – SVC POD tests (if required) at or below the current limits, where the PODs are progressively tested then enabled.

16.4.1 – QNI Less Than or at Current Limit (export and import respectively).

16.4.2 – QNI Less Than or at Current Limit (export and import respectively) – all PODs Enabled.

16.5 – The increased power transfer test hold points for Queensland export and import are described.

16.6 – Test Procedure for QNI Hold Point assessment (export and import respectively).

16.1 Summary of the Schedule of Tests

The tests are summarised in Table 16.1. Timing is subject to change depending upon project construction and equipment commissioning timeframes, power system conditions (including transfer level dictated by the market) as well as the commissioning process.

Table 16.1 Summary of the tests

Indicative timing	Transfer level requirement (both directions)	Testing	Additional notes
April to June 2022	Nil	<ul style="list-style-type: none"> SVC plant testing as part of the plant commissioning 	<ul style="list-style-type: none"> Not part of the 5.7.7 test process SVC PODs offline
June/July 2022	≤ 100% of current limit	Baseline Tests – Section 16.3	
		<ul style="list-style-type: none"> Online monitoring 	<ul style="list-style-type: none"> Monitoring for system normal and outage conditions which occur during the test period
		<ul style="list-style-type: none"> SVC voltage reference step tests 	<ul style="list-style-type: none"> +/- 5% voltage steps to be applied at Tamworth, Armidale and Dumaresq SVCs SVC PODs offline
		<ul style="list-style-type: none"> Switching of major 330 kV lines along the Bulli Creek - Dumaresq - Armidale corridor 	<ul style="list-style-type: none"> Trip and auto-reclose in 60s Lines to be determined - based on further analysis and staff availability
June /July 2022	Near to 100% of current limit	SVC POD tests – Section 16.4	Required only if pre-requisite power system analysis shows that PODs are required
		<ul style="list-style-type: none"> Online monitoring 	<ul style="list-style-type: none"> Monitoring for system normal and outage conditions which occur during the test period
		<ul style="list-style-type: none"> SVC voltage reference step tests 	<ul style="list-style-type: none"> +/- 5% voltage steps to be applied at Tamworth, Armidale and Dumaresq SVCs PODs enabled one at a time and recordings taken for a 3 hr period, +/- 5% voltage steps to be applied at the end of the monitoring period When all of PODs are proven they are then enabled sequentially. Further final test with all PODs in-service
		<ul style="list-style-type: none"> Sapphire Wind Farm voltage reference step tests 	<ul style="list-style-type: none"> +/- 5% voltage steps to be applied at Sapphire Wind Farm with all PODs enabled
		<ul style="list-style-type: none"> Switching of major 330 kV lines along the Bulli Creek - Dumaresq - Armidale corridor 	<ul style="list-style-type: none"> Trip and auto-reclose in 60s Lines to be determined - based on further analysis and staff availability
December 2022 ¹⁰ - 50% of the increase in capacity	100% of current limit and then in 50 MW increments (or higher)	Increased power transfer tests – see Section 16.5 for hold points and 16.6 for Tests.	

¹⁰ Depends on the availability of favourable test conditions and results.

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Indicative timing	Transfer level requirement (both directions)	Testing	Additional notes
Mid-2023 - full increase in capacity	increments subject to certain criteria) to the new maximum transfer limit		
		<ul style="list-style-type: none"> Online monitoring 	<ul style="list-style-type: none"> Monitoring for system normal and outage conditions which occur during the test period
		<ul style="list-style-type: none"> SVC voltage reference step tests 	<ul style="list-style-type: none"> +/- 5% voltage steps to be applied at Tamworth, Armidale and Dumaresq PODs online (if applicable)
		<ul style="list-style-type: none"> Switching of major 330 kV lines along the Bulli Creek - Dumaresq - Armidale corridor 	<ul style="list-style-type: none"> Trip and auto-reclose in 60s Lines to be determined - based on further analysis and staff availability
Mid-2023	Maximum transfer limit	Tests at maximum Queensland export and maximum NSW export (Section 16.6)	
		<ul style="list-style-type: none"> Online monitoring 	<ul style="list-style-type: none"> Monitoring for system normal and outage conditions which occur during the test period
		<ul style="list-style-type: none"> Sapphire Wind Farm voltage reference step tests 	<ul style="list-style-type: none"> +/- 5% voltage steps to be applied at Sapphire Wind Farm

16.2 Pre-requisites for Conducting Tests

The prerequisites for conducting the tests are:

- All of the new QNI plant is in service and successfully commissioned (except SVC PODs, if applicable) including associated EMS updates, and model alignment.
- The set of network constraints taking into account the impact of the new plant is implemented in market systems (NEMDE).
- The outcome of a pre-test risk assessment shows that the tests can proceed.
- The appropriate FCAS facilities are available for the line switching tests.
- The SVC PODs are enabled (if applicable and once proven) at power transfers beyond the existing QNI limits.

16.3 Baseline Tests

These tests establish a reference point for analysing the system performance and modelling at higher power transfers.

16.3.1 QNI Export and Import tests

The power transfer over QNI is driven by market conditions to near to the existing capability of 1200MW export and 600 import respectively.

Damping tests

- QNI power flow as driven by the market within the defined constraints.
- Continuous monitoring of system damping.
- Continuous monitoring of system disturbances.

Disturbance tests

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- Line switchings¹¹.
- Step changes (+/- 5%) to SVC voltage reference points at Tamworth, Armidale and Dumaresq.

Review Test Results

- Compare damping measurements with Mudpack simulation results from system snapshots downloaded from OPDMS.
- Compare records of the disturbance tests and any naturally occurring disturbances with simulations using as appropriate power system analysis software (e.g. Power Technologies International's PSS/E program and/or PSCAD) applied to the relevant system snapshots.
- Adjust the simulation model or model calibration if required. The simulation model calibration¹² and/or offset to the simulated damping will be adjusted, if required, to improve agreement with measurements.

16.4 SVC POD Tests

If pre-requisite power system analysis identifies the need for PODs, then the procedure for testing the SVC PODs is as follows.

16.4.1 QNI Less Than or at Current Limit (export and import respectively)

The QNI power transfer is driven by market conditions to a high level, at or below the current export and import limit respectively.

The procedure is identical for export and import and is to be completed for power follows in both directions as follows.

The PODs are activated one at a time for 3 hours until they are proven.

Sequential activation of the PODs:

Tamworth POD Activation

Activate the POD for 3 hours

De-activate the POD

Armidale POD Activation

Activate the POD for 3 hours

De-activate the POD

Dumaresq POD Activation

Activate the POD for 3 hours

De-activate the POD

Damping tests

- QNI power flow as driven by the market within the defined constraints.
- Continuous monitoring of system damping.
- Continuous monitoring of system disturbances.

Disturbance tests

¹¹ Lines to be determined - based on further analysis and location of staff.

¹² The calibration is determined by comparing actual system behaviour with the model outcomes. From previous analysis of the system and the measurement of the system damping response, the difference between models and actual behaviour is able to be quantified.

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- Line switchings¹³.
- Step changes (+/- 5%) to SVC voltage reference points at Tamworth, Armidale and Dumaresq.
- Step change (+/- 5%) to the voltage reference at Sapphire Wind Farm.

Review Test Results

- Compare damping measurements with Mudpack simulation results from system snapshots downloaded from OPDMS.
- Compare records of the disturbance tests and any naturally occurring disturbances with simulations using Power Technologies International's PSS/E program and/or PSCAD applied to the relevant system snapshots as required.

Assessment Criteria

The following criteria must be satisfied before proceeding:

- The system damping meets Rules requirements at all times.
- Responses to any disturbances meet system stability guidelines.
- Measured damping and responses to any disturbances align with simulations.

If the assessment criteria are met then proceed to test the next SVC POD. Once all of the PODs are tested advance to Section 16.4.2.

16.4.2 QNI Less Than or at Current Limit (export and import respectively) – all PODs Enabled

The QNI power transfer is driven by market conditions to a high level, at or below the current export and import limit respectively.

The procedure is identical for export and import and is to be completed for power follows in both directions as follows.

The Tamworth POD is enabled.

The Armidale POD is enabled and testing is undertaken.

The Dumaresq POD is enabled and further testing is undertaken.

Damping tests (once the second of the PODs is enabled and once all PODs are enabled)

- QNI power flow as driven by the market within the defined constraints.
- Continuous monitoring of system damping.
- Continuous monitoring of system disturbances.

Disturbance tests (once the second of the PODs is enabled and once all PODs are enabled)

- Line switchings¹⁴.
- Step changes (+/- 5%) to SVC voltage reference points at Tamworth, Armidale and Dumaresq.
- Step change (+/- 5%) to the voltage reference at Sapphire Wind Farm.

Review Test Results

- Compare damping measurements with Mudpack simulation results from system snapshots downloaded from OPDMS.

¹³ Lines to be determined - based on further analysis and location of staff.

¹⁴ Lines to be determined - based on further analysis and location of staff.

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- Compare records of the disturbance tests and any naturally occurring disturbances with simulations using Power Technologies International’s PSS/E program and/or PSCAD (as required) applied to the relevant system snapshots.

Assessment Criteria

The following criteria must be satisfied before proceeding:

- The system damping meets Rules requirements at all times.
- Responses to any disturbances meet system stability guidelines.
- Measured damping and responses to any disturbances align with simulations.

Once the assessment criteria are met, then the PODs are available for service for QNI power transfer in the direction tested (e.g. export). They may need to be disabled at this point in preparation for tests under QNI power transfers in the opposite direction (e.g. import). The order of testing under Queensland export or import conditions will depend on the prevailing market driven power flows.

Once the PODs are proven for Queensland export and import they will be enabled for normal service.

16.5 Increased Power Transfer Test Hold Points

The tests are conducted at various hold points. By increasing the power transfer represented at each hold point the power transfer capability of the interconnection is proven to be secure and can be released to the market.

The QNI flows will be driven by the market within the defined constraints. System damping will be continuously monitored during the hold point testing period. Larger system disturbances will be recorded if they occur. The nominated market driven test scenarios are required to be covered at each hold point before proceeding to the next hold point. The test scenarios are similar for each hold point except that some additional tests will be undertaken at the maximum power transfer.

System damping will be reviewed to determine whether the damping is satisfactory and what correction factor or offset needs to be applied to the level of damping obtained from Mudpack simulations. Simulation results, using system snapshots taken at the time of the tests, will then be used to show that system damping following the worst case contingency for each oscillatory mode would not fall below the level required in the Rules.

The hold points set out below are indicative at present. Damping studies and security assessments will be undertaken during the tests to provide guidance on the necessary increment to be applied to the hold points. It is possible that coarser increments will be able to be applied (e.g. 100 MW), which will result in the total number of tests for import and export conditions being reduced. Coarser increments could be applied subject to:

- No unexpected performance (including damping)
- Alignment of modelling within expected accuracy tolerance
- Endorsement from the test team.

Queensland Export Hold Points

For power transfer from Queensland to NSW it is assumed that the prevailing limit is 1200MW and hence each hold point MW has been quantified as an absolute level in Table 16.2 below.

Table 16.2 Queensland export hold points

Queensland Export Test Hold Point	Qld Demand	Transfer level (MW)	Testing season
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1	Low medium	Existing limit 1200	Summer
2	Low - medium	1250	Summer or winter
3	Low - medium	1300	Summer or winter
4	Low - medium	1350	Summer or winter
5	Low - medium	1370 (Note)	Summer or winter
6	Low	1400	Summer or winter
7	Low	1450	Winter conditions

Note: Secondary systems limitations at a northern NSW substation limit the capability for Queensland export to 1370MW. Until this limitation is removed the tests will be limited to this power transfer. At the time of publishing this test plan, this is anticipated to be before June 2023.

Queensland Import Hold Points

The existing power transfer capability from NSW to Queensland is governed by limit equations and varies over a wide range. Hence the absolute values of the hold points for power transfer in this direction shown in Table 16.3 below are indicative, starting from a base value of 600MW. These hold points for Queensland import have also been expressed as increments above the prevailing limit capability.

Table 16.3 Queensland import hold points

Queensland Import Test Hold Point	NSW Demand	Indicative Power Transfer Level (MW)	Increment in Transfer level (MW) above the prevailing capability	Testing season
1	Low medium	Existing limit 600	Existing limit	Not critical
2	Low - medium	650	50	“
3	Low - medium	700	100	“
4	Low - medium	750	150	“
5	Low- medium	800	200	“
5	Low	850	250	“
7	Low	900	300	“
8	Low	950	350	“

16.6 Test Procedure for QNI Hold Point assessment (export and import respectively)

For each hold point in-turn the QNI power transfer is driven by market conditions to near to the capabilities as defined in Tables 16.2 and 16.3. Successful completion against the assessment criteria is a pre-requisite for moving to the next hold point.

Damping tests

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- QNI power flow as driven by the market within the defined constraints.
- Continuous monitoring of system damping.
- Continuous monitoring of system disturbances.

Disturbance tests

- Line switchings¹⁵.
- Step changes (+/- 5%) to SVC voltage reference points.
- Step change (+/- 5%) to the voltage reference at Sapphire Wind Farm.

Review Test Results

- Compare damping measurements with Mudpack simulation results from system snapshots downloaded from OPDMS.
- Compare records of the disturbance tests and any naturally occurring disturbances with simulations using Power Technologies International's PSS/E program and/or PSCAD (as appropriate) applied to the relevant system snapshots.
- Adjust the simulation model or model calibration if required. The simulation model calibration and/or offset to the simulated damping will be adjusted, if required, to improve agreement with measurements.

Assessment Criteria

The following criteria must be satisfied before proceeding to the next hold point:

- The system damping meets Rules requirements at all times.
- Responses to any disturbances meet system stability guidelines.
- Measured damping and responses to any disturbances align with simulations.
- Review Mudpack results for the next hold point taking into account the worst case contingency.

If the assessment criteria are met then proceed to the next hold point.

¹⁵ Lines to be determined - based on further analysis and location of staff.

APPENDIX A – TEST PROCESS CHARTS

Figure 2 - Process for moving between hold points

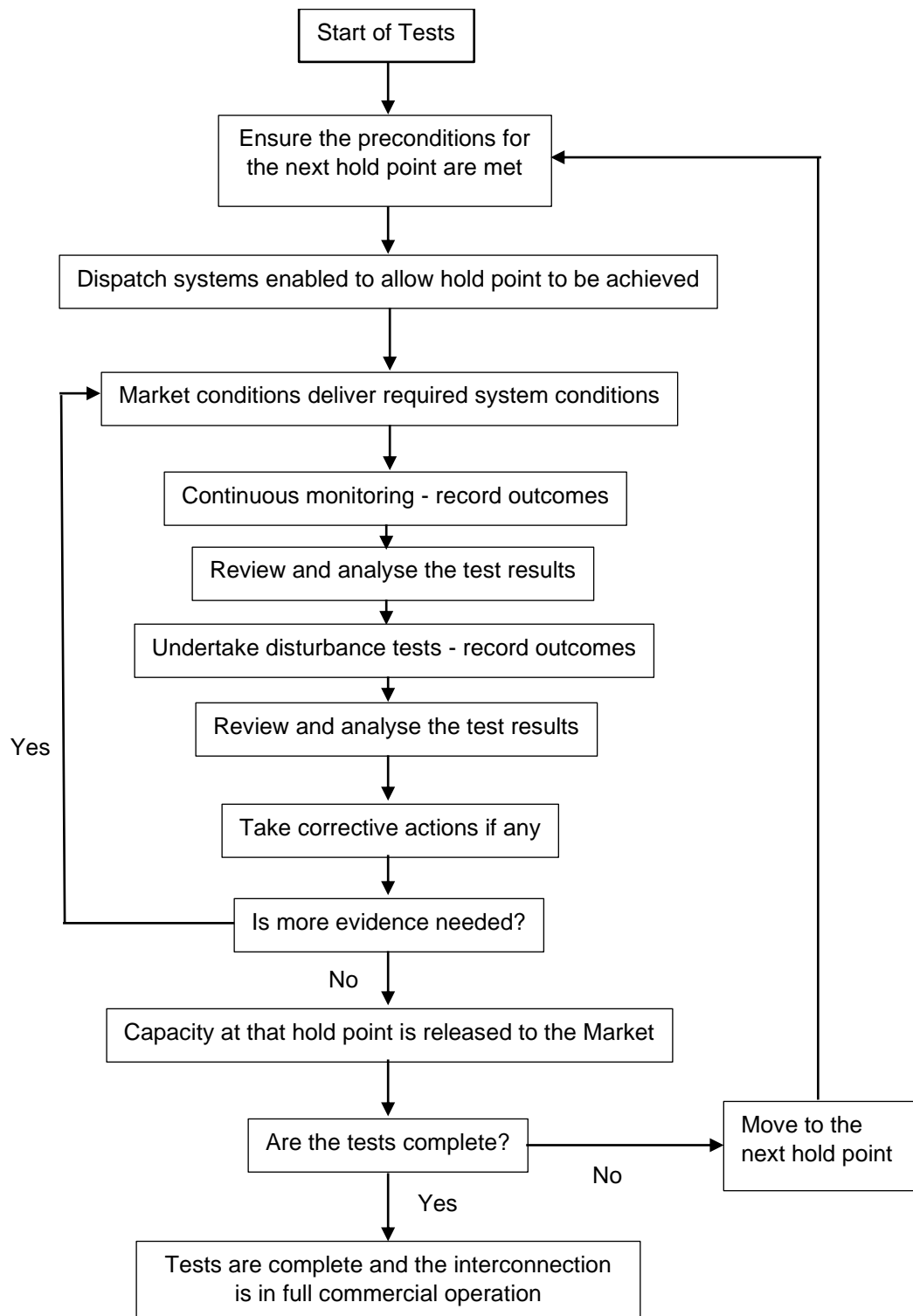
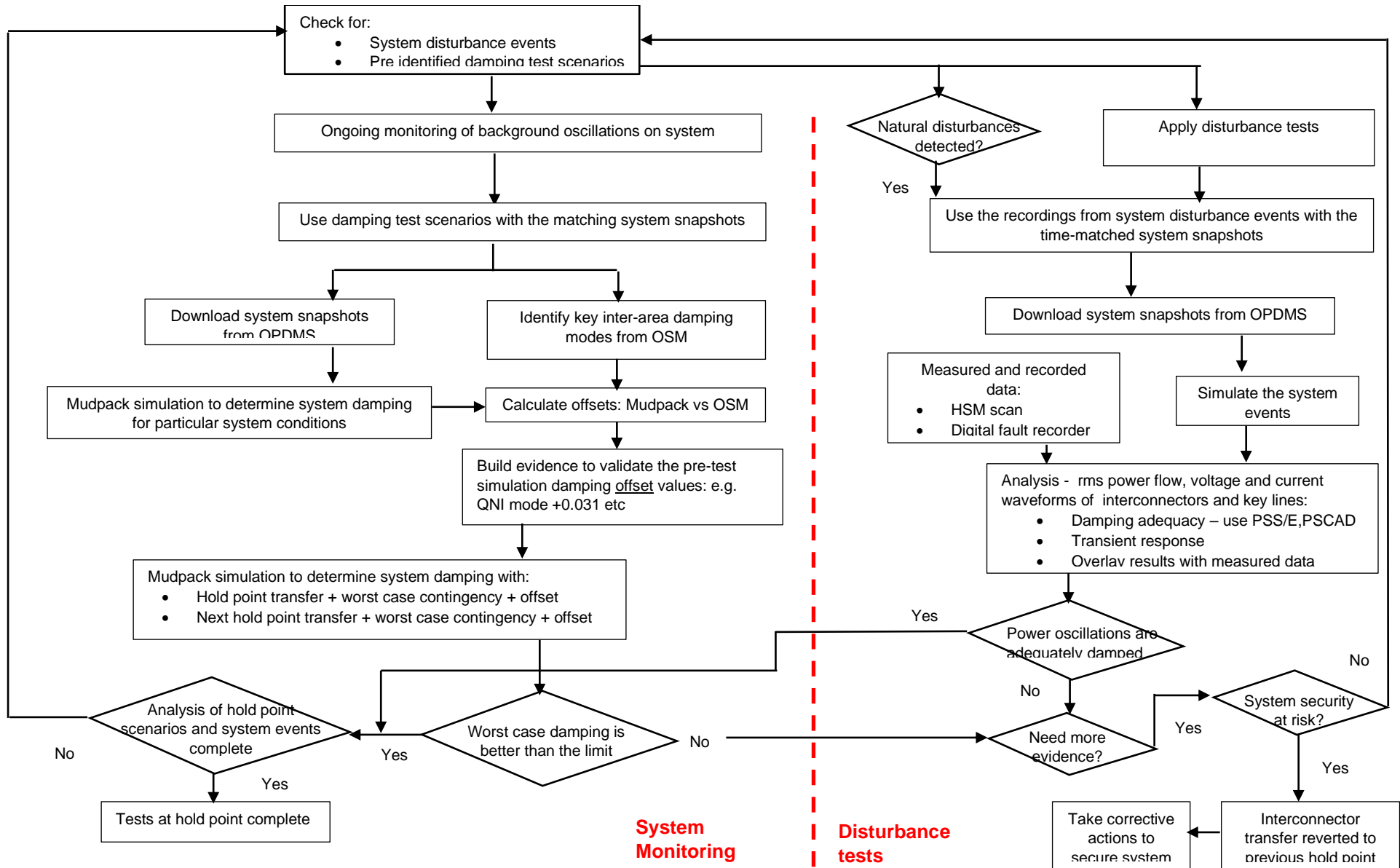


Figure 3 - Analysis process



APPENDIX B – CONSTRAINTS AFFECTING QNI TRANSFER

Work is underway to finalise the constraint equations that represent the voltage stability and transient stability limitations, under system normal conditions, that will apply following the completion of the QNI upgrade works. The constraint equations will be included in the NEM dispatch systems.

Plant thermal rating limitations will also be addressed under the normal market dispatch systems.

APPENDIX C- MONITORING AND RECORDING

The monitoring and recording of the system response to small natural disturbances and larger-scale disturbances is through high speed monitors and the oscillatory stability monitors. These are located at strategic locations on the interconnected network. The following information is tentative at this stage.

High Speed Monitors (HSM)

Generally, the HSM systems directly measure 3 phase-to-ground voltage and 3 phase current. They calculate 3 phase real power, 3 phase reactive power, positive sequence voltage magnitude, angle and frequency.

The following existing HSMs will be used to monitor and record inter-network test results for QNI.

Queensland

- Braemar 275kV Switchyard
- Millmerran 275kV Switchyard
- Halys 275kV Switchyard

NSW

- Dumaresq 330kV Switching Station
- Armidale 330kV Switchyard
- Tamworth 330kV Switchyard
- Sydney West 330kV Switchyard
- Murray 330kV Switching Station

Recordings from the following HSMs may also be required for the tests. These details will be determined through further analysis.

Victoria

- Dederang 330kV Terminal Station
- South Morang 330kV Terminal Station
- Heywood 275kV Switchyard

South Australia

- South East 275kV Switchyard
- Tailem Bend 275kV Switchyard
- Para 275kV Switchyard
- Davenport 275kV Switchyard
- Robertstown 275kV Switchyard

Transgrid and Powerlink will analyse HSM recordings.

Continuous slow scan 50 Hz data are stored for two weeks. A number of the Victorian HSMs are configured to trigger a slow scan data recording automatically for network disturbances. The triggered data are polled periodically and downloaded by the OPDMS system to CSV files on a file share. User tagged events are transferred to long-term storage and continue to be available through the OPDMS system.

Many of the HSMs include a Digital fault Recorder (DFR) function which are currently capable of recording in excess of 128 samples per cycle. One month prior to start of the testing selected monitors will have their pre fault length and post fault length set to 1 s and 4 s respectively. The sampling rate should be in excess of 64 samples per cycle.

Oscillatory Stability Monitoring (OSM)

OSM (Oscillatory Stability Monitor) uses phasor measurement unit (PMU) measurements to produce real-time parameter estimates of the oscillatory modes in the NEM, based on a modal-identification algorithm developed by Queensland University of Technology (QUT) and Transgrid. The OSM also includes the Psymetrix PhasorPoint real-time oscillatory stability tool, which uses the same PMU measurements.

OSM data can be accessed using a PI datalink in Excel. Quantities such as angles, kV, kA and modes are stored.

There are three main modes of oscillation on the interconnected system:

Mode 1: The QNI mode

Mode 2: The I25 mode

Mode 3: The I35 mode.

The Psymetrix PhasorPoint system is a phasor-based Wide Area Monitoring System (WAMS) that analyses and monitors power networks using modern phasor measurement appliances. A phasor-based WAMS is a network of fast synchronised measurements of voltage and current phasors (synchrophasors) that enables users to monitor the angular stability and dynamics of a power system. The PhasorPoint application is currently used by AEMO to monitor the small signal stability of some known oscillation modes.

Monitoring of System Disturbances

AEMO System Market Incident Reporting Kiosk (SMIRK) reports, NEM RTO Daily reports and EPSOC logs can be used to identify system disturbance events and details of the disturbance. SMIRK reports include time of the incident, its description and invoked constraint details etc. NEM RTO Daily Reports include a high level summary of the last 24 hours of NEM operations including frequency events, unplanned outages, lack of reserve conditions (LOR) and line reclassifications etc. EPSOC logs include high-level event descriptions which can be sorted by region and time.

Identifying Damping Test Scenarios

NEO is a data analysis, viewing and accessing tool from the AEMO WARE database. NEO is useful to view regional demand, interconnector flows, wind forecast and reserve data etc.

NEO and Pi ProcessBook (or datalink) can identify system scenarios suitable for analysis for inter-network testing purposes.

The Pi system is capable of collecting, storing and presenting historical and near real time data. Pi ProcessBook is an application with built in displays to visualise trends, dynamic bars, current values, time based summary data, etc. that can update in near real time. Pi datalink is an Excel add-in that allows data to be retrieved into a spreadsheet and then processed with normal spreadsheet operations.

Other Systems

In addition, it is expected that AEMO, Powerlink and Transgrid will utilise the following information sources during the test period:

- Outage scheduling systems including the AEMO Network Outage Scheduler (NOS).
- NEO to assess reserve conditions throughout the test program.
- BOM weather forecasts and weather warnings.
- Other systems as required.