PROJECT ENERGYCONNECT STAGE 1 AND HEYWOOD INTERCONNECTOR - DRAFT TEST PROGRAM FOR INTER-NETWORK TESTS

Market Consultation Draft Document

Version Release History

VERSION	DATE	BY	REVIEWED	CHANGES
1	16/10/23	PEC System Integration Steering Committee (SISC) Inter-network testing workstream	PEC SISC	Draft for initial feedback from the System Integration Steering Committee
2	31/10/23	PEC SISC Inter-network testing workstream	PEC SISC	Draft for consultation with jurisdictional planning representatives and inter-network test reference committee
3	21/11/2023	PEC SISC Inter-network testing workstream	PEC SISC	Draft for public consultation

Abbreviations

Abbreviation	Term
AEMO	Australian Energy Market Operator
AVP	AEMO Victorian Planning
DFR	Digital Fault Recorder
HIC	Heywood Interconnector
HSM	High Speed Monitoring
HVDC	High Voltage Direct Current
MINI	Material Inter-network Impact
MW	Megawatts
NEM	National Electricity Market
NEMDE	NEM Dispatch Engine
NER	National Electricity Rules
NSW	New South Wales
OPDMS	Operational Data Management System (OPDMS)
OSM	Oscillatory Stability Monitoring
PASA	Projected Assessment of System Adequacy
PEC	Project EnergyConnect
PMU	Phasor Measurement unit
POD	Power Oscillation Dampers
PSS	Power System Stability
PST	Phase Shifting Transformer
QUT	Queensland University of Technology
S_East	South East
SA	South Australia
SPS	Special Protection Scheme
SVC	Static Var Compensator
Syncon	Synchronous Condenser
T-Bend	Tailem Bend
TF	Transformer
TNSP	Transmission Network Service Provider

Contents

Important Notice

Purpose

This document has been prepared by Transgrid, ElectraNet and AEMO Victorian Planning (AVP, in its capacity as Victorian transmission planner) (See Appendix C – Project Proponents) in consultation with AEMO. The document is provided for consultation with Registered Participants as required by Clause 5.7.7(p) of the National Electricity Rules (Rules), and 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 ElectraNet have made every effort to ensure the quality of the information but cannot guarantee its accuracy or completeness.

Accordingly, to the maximum extent permitted by law, AEMO, Transgrid and ElectraNet and their officers, employees and consultants involved in the preparation of this report:

- make no representation or warranty, express or implied, as to the currency, accuracy, reliability or completeness of the information in this document; and
- are not liable (whether by reason of negligence or otherwise) for any statements or representations in this document, or any omissions from it, or for any use or reliance on the information in it.

1 Scope

This draft inter-network test program document for Project EnergyConnect[1] (PEC) Stage 1 and the increase in the power transfer capability over the Heywood Interconnector[2] (HIC), has been prepared for consultation with Registered Participants in accordance with the requirements of clause 5.7.7 of the National Electricity Rules (Rules), which deals with inter-network tests. The inter-network test program encompasses testing to give confidence in the operation and release of capacity of the upgraded system.

The components of the project have been identified as having a material inter-network impact (MINI)[3]. In accordance with clause 5.7.7 of the Rules and the Inter-Network Test Guidelines[4], AEMO has determined that inter-network tests are required. In addition, AEMO has determined that additional prudent tests are required as PEC is a new interconnector, between New South Wales (NSW) and South Australia (SA) regions for the first time. Inter-network tests for the PEC Stage 1 and the HIC upgrade are intended to:

- Quantify the impact of connection of PEC Stage 1 and increase of HIC capacity on damping of modes of oscillation, to ensure they meet Rules requirements,
- Validate interconnector power transfer capability, and
- Additionally, through the course of testing, to:
  - Ensure the satisfactory coordination of transmission equipment and generator plant control systems.
  - Identify potential operational issues at increased transfer, such as interconnector drift management issues.
  - Identify any unmodelled phenomena.

At the time of publishing this document, Transgrid and ElectraNet intend to complete pre-commissioning activities including factory and site acceptance testing for PEC Stage 1 ready for synchronisation across the SA and NSW regions and commencement of inter-network testing in April 2024.

AEMO, ElectraNet, Transgrid and AVP invite feedback on this test program. In particular, feedback is requested on proposed tests, test methodology including monitoring and risk mitigation, and hold points.

The specific tests outlined in this test program are subject to further assessment by AEMO, Transgrid, ElectraNet and AVP and may be amended between the publication of this draft test program and the final test program.

2 Background

2.1 Project EnergyConnect stage 1

PEC Stage 1 comprises the following transmission works:

- A double circuit 275 kV line between Robertstown and Bundey in South Australia.
- One circuit of the 330 kV double circuit line from Buronga in NSW to Bundey in SA.

[1] Project EnergyConnect is a new interconnector connecting the South Australia and New South Wales regions. https://www.projectenergyconnect.com.au/

[2] Heywood interconnector is a double circuit interconnector connecting the South Australia and Victoria regions.

[3] These assessment are guided by the principles in the Criteria for Assessing Material Inter-Network Impact of Transmission Augmentations https://aemo.com.au/-/media/files/electricity/nem/network_connections/transmission-and-distribution/170-0035-pdf.pdf

[4] See https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2023/inter-network-test-guidelines/final-documents/inter-network-test-guidelines-v22-clean.pdf?la=en

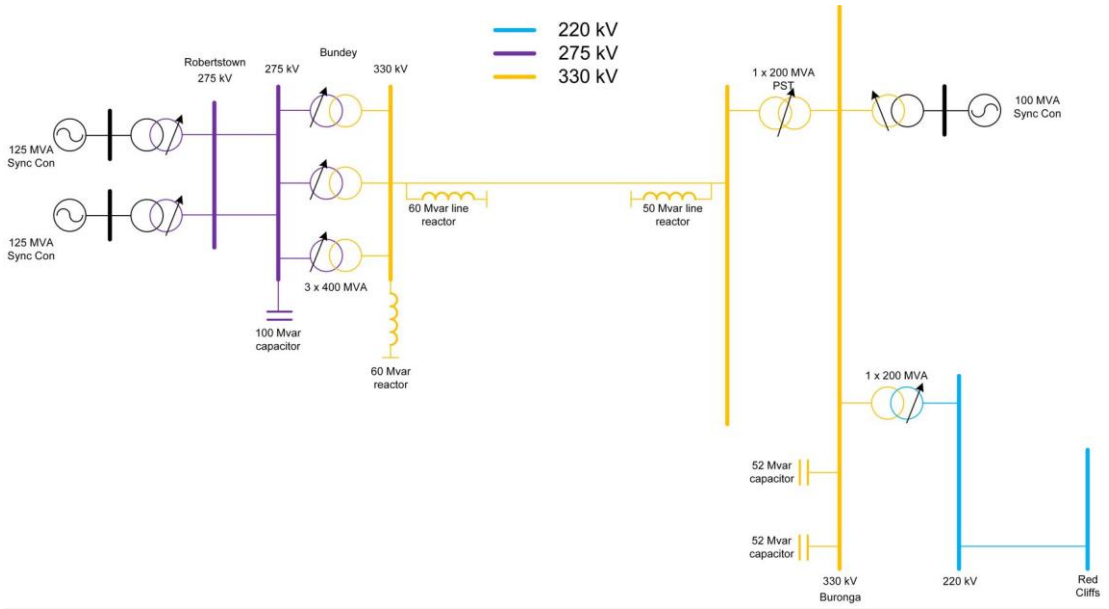
- Installation of one 330 kV Phase Shifting Transformer (PST) at Buronga to control the power flow on the single 330 kV circuit from Buronga to Bundey.
- Installation of one 330/220 kV transformer at Buronga.
- Completion of two 220 kV circuits between Buronga and Red Cliffs in Victoria to replace the existing line*.
- Installation of three 330/275 kV transformers at Bundey.
- Shunt capacitor and shunt reactor installations at Bundey 330 kV, Bundey 275 kV and Buronga 330 kV*.
- Installation of one synchronous condenser (syncon) at Buronga (330 kV).
- Installation of secondary systems (communications, control and protection) in NSW, SA and Victoria.
- Installation of System Protection Schemes in SA as well as potential modifications to existing schemes across NSW, Victoria and SA.

PEC Stage 1 will operate in parallel with the existing Heywood and Murraylink interconnectors and has a capacity of 150 MW for SA import and export.

*PEC Stage 1 inter-network testing may commence prior to the second 220 kV circuit between Buronga and Red Cliffs circuit and prior to all of the shunt capacitors at Bundey 330 kV, Bundey 275 kV and Buronga 330 kV being available for operational service[5].

Figure 1 below shows the first stage of the PEC development.

Figure 1: PEC Stage 1 development



2.2 Heywood Interconnector remaining capacity release

The HIC[6] upgrade project was completed in 2016 to increase HIC capacity from 460 megawatts (MW) to 650 MW in both directions. Inter-network testing was commenced in 2016 and to date has only

[5] Transgrid have assessed the impact of commencing inter-network testing prior to these assets being ready for operational service and have confirmed that inter-network test results will still be valid and adequately represent final PEC Stage 1 performance.

[6] The inter-network testing to increase the HIC power transfer capability, outlined in this document, supersedes the inter-network test program that was published for HIC testing by AEMO here - https://aemo.com.au/-/media/archive/files/electricity/consultations/2015/hyts-interconnector-upgrade-internetwork.pdf

released 550MW SA export and 600 MW SA import capacity. In addition to PEC Stage 1 inter-network testing, this test program includes testing to release the full capacity on the HIC.

2.3 Murraylink High Voltage DC (HVDC) interconnector

The Murraylink High Voltage Direct Current (HVDC) interconnector (Murraylink) between South Australia and Victoria has a power transfer capability of:

- SA export: 200 MW.
- SA import: 220 MW.

Murraylink capability is not affected by PEC or additional HIC capacity release.

2.4 Combined AC capacity

Upon completion of PEC Stage 1 and HIC inter-network testing, the target combined[7] AC capacity is:

- SA export: 700 MW.
  SA import: 750 MW.

3 Requirements of the Rules addressed in this test program

AEMO in its capacity as system operator of the National Electricity Market, and each of the Proponents, have identified that inter-network testing will be required in accordance with clause 5.7.7(g). Development of this test program covering all components of the project has been jointly coordinated by AEMO, Transgrid, ElectraNet and AVP.

A previous draft version of the test program was provided to Jurisdictional Planning Representatives in accordance with clause 5.7.7(f) of the Rules, and to the Inter-network Test Reference Committee in accordance with the Inter-Network Test Guidelines, for consultation.

In determining the test program, clause 5.7.7(r) of the Rules requires AEMO to have regard to the following principles:

(1) power system security must be maintained in accordance with Chapter 4; and
(2) the variation from the central dispatch outcomes that would otherwise occur if there were no inter-network tests should be minimised; and
(3) the duration of the tests should be as short as possible consistently with test requirements and power system security; and
(4) the test facilitation costs to be borne by the Proponent under paragraph (aa) should be kept to the minimum consistent with this paragraph.[8]

Principle 1

At all times, AEMO will have sole management of power system security, and no variation to the requirements of Chapter 4 are required by these tests. Switching or disturbance tests may only be carried out under system conditions where in AEMO's view power system security can be maintained.

Principle 2

System conditions for conduct of the tests will be achieved through normal market dispatch and utilisation of PST tap settings to achieve desired power transfer on PEC where possible. Therefore, the test approach represents minimal distortion of market outcomes.

Principle 3

The main determinant of the time required for a system damping test is the duration of data acquisition needed to characterise the frequency and damping of oscillation modes. Experience from

[7] ElectraNet studies found that the PEC Stage 1 and HIC combined capacity must be limited to 700 MW SA export and 750 MW SA import to maintain transient stability in SA after credible contingency events.
[8] Not applicable as test facilitation services have not been procured for these tests.

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.

Where a test involves a deliberate disturbance to the system the time required for a test is determined by the time to activate the disturbance and observe the immediate system response and then the time for the system to settle into a new post-disturbance state. Time is also required to restore the system to its pre-test condition.

Principle 4

It is planned to rely on market dispatch to achieve the necessary conditions for testing. In addition, this test program does not envisage it will be necessary for AEMO to apply inter-network testing constraints (as contemplated by the clause 5.7.7(ac) of the Rules) to establish conditions necessary for the inter-network tests (refer to Section 9 of this document).

4 Inter-network test pre-requisites

Prior to the commencement of the inter-network tests there are a number of pre-requisites that must be met.

Assets Ready for Service

All new equipment (e.g. syncons, PSTs) have been fully commissioned by the TNSP, and the test results reviewed and accepted by AEMO. All PEC Stage 1 high voltage transmission assets and secondary systems have been commissioned and are ready for service, prior to AEMO approval for first synchronisation of PEC stage 1.

Provision of power system model information

PEC Stage 1 models have been validated and demonstrated as fit for purpose for use in power system simulation software (e.g. PSS/E, PSCAD and MUDPACK) and accepted by AEMO and the TNSPs in accordance with clause 4.3.4(o) of the Rules.

Subject to agreement between AEMO, ElectraNet and Transgrid, and provided there are no material issues with model accuracy, provision of post-commissioning R2 data is not a pre-requisite for commencement of inter-network testing.

Limit Equations

Limit equations have undergone due diligence analysis by AEMO and are included in market systems (the NEM Dispatch Engine, or NEMDE) as constraint equations. If AEMO considers material power system changes have occurred in SA, VIC or NSW prior to commencement of testing, ElectraNet, Transgrid and AVP will be required to provide updated limits advice to AEMO and AEMO will complete due diligence analysis on this advice as a pre-requisite to inter-network testing.

Special Protection Schemes

New/modified Special Protection Schemes (SPS) have been fully tested and are ready for service.

Control systems changes

Any changes to control system settings including power system stabilisers and power oscillation damper settings have been reviewed and accepted by AEMO.

If system studies show the need for re-tuning of existing Power System Stabilisers (PSS) and Power Oscillation Dampers (POD) or the enabling of the PODs to on the Buronga syncon, then these will have been fully designed, approved and commissioned prior to the commencement of inter-network tests. Pre-commissioning includes ensuring models for plant and equipment added as part of PEC Stage 1 are adequate for commencement of testing. Factory Acceptance Test (FAT) and Site

Acceptance Test (SAT). Alternatively, additional damping constraints may be applied should system studies indicate insufficient damping for specific operating conditions.

5 Test methodology

5.1 Test conditions

Tests will involve continuous monitoring of system damping with tests usually undertaken starting with the network in a system normal condition. Test conditions are to be defined in terms of key system variables that affect system damping and the dynamic response of the system. Some may include:

- A range of demands and generation dispatch patterns across the NEM.
- Power transfer from SA to NSW via PEC over the full range of the capability.
- Power transfer from NSW to SA via PEC over the full range of the capability.
- Power transfer between regions (SA, VIC and NSW).
- Switching of key network elements.
- Step changes in voltage control settings.

System conditions for conduct of the tests will be achieved through normal market dispatch and utilisation of PST tap settings to achieve desire power transfer on PEC where possible.

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 syncons / Static Var Compensators (SVC) and major transmission lines. AEMO, Transgrid, ElectraNet and AVP 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 adversely impact the market.

Flowcharts in Appendix A illustrate the process for progressing between test hold points and for reviewing and assessing test results.

5.2 Generic system damping (GSD) assessment

Most 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 the generic damping assessment. 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:

- Pre-test simulations of the expected damping performance.
- Continuous security monitoring by AEMO.
- Allowing the market to deliver the desired flow conditions, to be specified in the detailed test procedures.
- Observation and monitoring of system damping for the required period - a period of at least 3 hours is anticipated for each test.
- 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.

5.3 Disturbance/switching tests

For disturbance tests, the system operating point will be deliberately disturbed to excite system oscillations and to measure their decay, as well as identify potential for control system interactions.

Various tests will be conducted at specified hold points (see Section 6). The types of disturbances include the switching of following transmission assets and applying step changes to voltage control reference points at selected generators and syncons / SVCs that have a voltage control function:

- Switching of the 330 kV line between Buronga and Bundey.

- Switching of one of the 275 kV lines between South East (S_East) and Tailem Bend (T_Bend) and/or bypass of the Black Range (Black_R) series capacitors.
- Switching one of the 275 kV lines between Robertstown (R_Town) and Tungkillo (Tunkil).
- Subject to confirmation with APA, fast run back of Murraylink (MLNK) HVDC interconnector and apply a reactive power output step change to the Murraylink converter system
- Switching of the 330/220 kV Buronga Transformer (TF).
- Applying a voltage step change to the Buronga Syncon.

In all line and transformer switching tests, the line/transformer will be opened and closed/switched back into service within 120 seconds and the system response will be recorded.

To manage the risk to the system of the switching of the 330 kV lines between Buronga and Bundey and the lines making up the HIC, the duration of a line switching test is limited to 120 seconds. Whilst 120 seconds will not allow the quantification of the actual damping levels of system oscillatory modes, it will indicate that transients have adequately decayed. Following the line opening, it is expected that the initial transients would die out over some seconds leaving at least 120 seconds observe the occurrence of any underlying sustained oscillations.

Switching tests are planned to be initiated by a manual open and close from the TNSP's network control room.

Prior to the commencement of the inter-network test, AEMO will assess the reserve conditions and the level of frequency control ancillary services available or dispatched through the market at the time.

Transmission equipment switching tests will not require staff to be on-site at the relevant substations unless, in AEMO's opinion, a delay in the switched line's return to service would lead to an Lack of Reserve (LOR) level 1 condition. If a delay in the switched line's return to service would lead to an LOR1 condition, a line switching test may still proceed if suitable staff are on-site.

Murraylink HVDC interconnector is unlikely to complete an open and close operation within a 120 second interval. To minimise the system security impact this testing can only be performed at the low PEC and HIC interconnector transfer levels.

5.4 Continuous monitoring

Large-scale disturbances to the operating conditions of the system may occur during the inter-network testing window due to external events. These events may be caused, for example, by the tripping of lines or plant.

Existing monitoring equipment records external/other 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 external 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.

5.5 Control system coordination (CSC) tests

The control systems on transmission plant and on generators in the NEM are coordinated to ensure that they respond appropriately to system disturbances.

Various tests will be conducted at specified hold points (see Section 6). The types of disturbances that will be considered by the test team may include:

- Disturbances identified in Section 5.3.
- Switching of reactive plant.
- Applying a step voltage change to a selected SVC reference voltage.

5.6 Buronga PST tapping test

PST tapping[9] testing will be undertaken at the first synchronisation across the Buronga – Bundy 330 kV line. The PST tap changer will be set to manual control mode and at a specific tap position (determined by Transgrid pre test simulation studies) prior to first synchronisation. Once the Buronga – Bundy 330 kV line is energised, the PST tap position will be manually tapped in both directions. The change of PEC and HIC power flow in response to PST tap position and correct tap changer operation will be monitored.

6 Test procedure

This section sets out the procedure for carrying out the tests for PEC Stage 1 and for increasing power transfer capacity of HIC. Tests will be conducted at successive hold points and reviewed prior to releasing inter-network capacity in accordance with the process outlined in Appendix A. Additionally, tests such as those described in Section 5.3 or 5.5 may be considered appropriate and undertaken as part of the test program.

6.1 Summary of PEC Stage 1 tests

The structure of the inter-network tests for PEC Stage 1 is shown in Table 1. Positive numbers indicate SA export and negative numbers indicate SA import.

In addition to the specific tests listed below, continuous monitoring of performance in response to natural disturbances (Section 5.4) will occur throughout the test program, and Generic System Damping Assessment (Section 5.2) will be evaluated at each hold point.

Table 1: Summary of PEC Stage 1 tests

Hold point	HIC transfer (MW)	PEC-1 transfer (MW)	Test no.	Test Type	Transmission equipment
1	< -500	Not synchronised	1.1	Switching test (Section 5.3)	S_East – T_Bend 275 kV line or R_Town – Tunkil 275 kV line
2	> 500	Not synchronised	2.1	Switching test (Section 5.3)	S_East – T_Bend 275 kV line or R_Town – Tunkil 275 kV line
3	-350 to 350	-50 to 50	3.1	Tapping test	Buronga PST
			3.2	Switching test (Section 5.3)	S_East – T_Bend 275 kV line or R_Town – Tunkil 275 kV line
			3.3	Switching test (Section 5.3)	Buronga – Bundey 330 kV line
			3.4	Switching test (Section 5.3)	MLNK interconnector (runback from 100-200 MW to 0 MW)
			3.5	Switching test (Section 5.3)	MLNK interconnector (reactive power output change from 150-MVar to 0 MVar) or Buronga syncon (5% voltage reference step change)
4	-500 to - 600	-125 to - 150	4.1	Switching test (Section 5.3)	S_East – T_Bend 275 kV line or R_Town – Tunkil 275 kV line
			4.2	Switching test (Section 5.3)	Buronga – Bundey 330 kV line
			4.3	Switching test (Section 5.3)	MLNK interconnector (reactive power output change from 150-MVar to 0 MVar) or Buronga Syncon (5% voltage reference step change)

[9] This test is a pre-requisite to inter-network testing and is required to confirm the performance of the tap changer and the impact on the share of flow on HIC and PEC

Hold point	HIC transfer (MW)	PEC-1 transfer (MW)	Test no.	Test Type	Transmission equipment
5	500 to 550	125 to 150	5.1	Switching test (Section 5.3)	S_East – T_Bend 275 kV line or R_Town – Tunkil 275 kV line
			5.2	Switching test (Section 5.3)	Buronga – Bundey 330 kV line
			5.3	Switching test (Section 5.3)	MLNK interconnector (reactive power output change from 150-MVar to 0 MVar) or Buronga Syncon (5% voltage reference step change)

6.2 Summary of HIC tests

On completion of the PEC Stage 1 tests outlined in Table 2, HIC tests are planned in order to complete outstanding inter-network testing. The proposed tests are summarised in Table 2 below. Positive numbers indicate SA export and negative numbers indicate SA import.

In addition to the specific tests listed below, continuous monitoring of performance in response to natural disturbances (Section 5.4) will occur throughout the test program, and Generic System Damping Assessment (Section 5.2) will be evaluated at each hold point.

Table 2: Summary of HIC tests

Hold point	HIC transfer (MW)	PEC-1 transfer (MW)	Test no.	Test Type	Transmission equipment
6	600	0 to 100	6.1	Switching test (Section 5.3)	S_East – T_Bend 275 kV line or R_Town – Tunkil 275 kV line
			6.2	Switching test (Section 5.3)	Buronga – Bundey 330 kV line
7	650	0 to 50	7.1	Switching test (Section 5.3)	S_East – T_Bend 275 kV line or R_Town – Tunkil 275 kV line
			7.2	Switching test (Section 5.3)	Buronga – Bundey 330 kV line
8	-650	0 to -100	8.1	Switching test (Section 5.3)	S_East – T_Bend 275 kV line or R_Town – Tunkil 275 kV line
			8.2	Switching test (Section 5.3)	Buronga – Bundey 330 kV line

7 Timing of tests

The capacity of PEC Stage 1 and the HIC will be progressively released to the market once the testing at each hold point has been completed, the results analysed and assessed as per the assessment criteria set out in this document.

At the time of preparing this test program indicative timings for the release of capacity are as follows[10]:

- PEC Stage 1 capacity – July 2024 (approximately 3 months after completion of all inter-network testing pre-requisites outlined in Section 5 of this test program).
- HIC upgrade full capacity – October 2024.

These timings will be updated at the time when the tests are planned to commence via Market Notices and AEMO fortnightly industry briefings. Further detail is provided in Section 9 of this test program.

[10] This depends on the availability of favourable test conditions and results.

8 Management of power system security

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. Any 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, ElectraNet and AVP 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 levels[11]. In this case tests may need to be cancelled and interconnector transfers reduced.
- AEMO, Transgrid, ElectraNet and AVP will monitor the system responses in real time using the online monitoring tools during the inter-network testing. If the measured responses are outside of the Rules requirements for stability[12] or not as anticipated, the test will be cancelled and remedial actions will be taken immediately to secure the system. The proponents confirm that suitable staff will be available to deploy to the sites to provide remedial action if required.

Under clause 5.7.7(ad) of the Rules, 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 10.

There is no need for special contingency arrangements in conducting any test as all tests will be carried out under secure conditions applicable to the future commercial operation of PEC Stage 1 and HIC. The normal security-constrained dispatch provided by NEMDE will ensure sufficient generation reserves across the NEM.

9 Required power system conditions

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, in the system remote from PEC and HIC, 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 AEMO, Transgrid, ElectraNet and AVP through power system analysis.

System conditions for conducting a damping test will generally require total power transfer in a specified direction between SA, NSW, Victoria and possibly 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. The Buronga PST may be used to help achieve the required power transfers on PEC Stage 1. In addition, any testing will be subject to consideration of the guidelines outlined in Section 10 of this test program.

This test program does not include utilisation of 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.*

[11] Similarly for an outage of Psymetrix, interconnector constraints are invoked.

[12] https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/power-system-stability-guidelines.pdf?la=en

At the time of preparing this test plan it is planned to rely on market dispatch to achieve the necessary conditions for testing. For PEC Stage 1 it is foreseeable that given the relatively low capacity and utilisation of PSTs this would be achievable. For HIC this may be less probable given:

- the relatively short duration of time HIC is at its limit,
- measures in place to mitigate interconnector drift, and
- potential mitigations needed to cater for NEM contingency events leading to overload of HIC during conditions SA is exporting to Victoria.

Should the critical range of required conditions not be obtained within a reasonable period of time, Transgrid, ElectraNet or AVP 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 plan will be updated accordingly.

10 Guidelines and decision making for tests

A test will be scheduled based on:

- NEMDE pre-dispatch indicating:
  - Ability to achieve the required interconnector transfer in the specified direction within security constraints.
  - Regional demands and transfers on interconnectors consistent with the test scope.
  - No planned switching of other critical interconnecting lines during the period.
- Availability for service of all apparatus and measurement systems 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 the test or any part of it or vary the procedure if reasonably necessary to do so in line with the following guidelines set by AEMO:

- There is a predicted inability to maintain power system security 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 SA and NSW / Victoria.
- 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.
- The Test Co-ordinator and test team agree that sufficient evidence has been gathered and assessed from testing at a particular hold point to justify moving to the next hold point, prior to completing all of the tests listed in Table 1 and Table 2.
- 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, syncon or SVC occurs.
- There is an issue with any transmission plant that may impact the test.
- High speed monitoring equipment is out of service.
- 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, ElectraNet and AVP).

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

11 Test analysis

11.1 Measuring the Power System Response

The power system response will be monitored using existing, permanently-installed measuring equipment (See Appendix B) at a number of locations across the NEM. This equipment will record all system data required for the inter-network tests. It includes the following:

11.2 Analysis of test results

At each testing stage, AEMO, Transgrid, Electranet and AVP will assess the measured levels of performance 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 the system performance in accordance with Rules requirements.
- 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, reformulation of limit advice, vary the test procedure or necessitate a delay to testing while the discrepancy is investigated.

11.3 Assessment Criteria

At each testing stage, AEMO, Transgrid, ElectraNet and AVP will assess the measured levels of damping and compare these with computer-based damping analysis applied to system load flow "snapshots" from OPDMS. AEMO, Transgrid, ElectraNet and AVP will also assess the dynamic response of the system to disturbances and compare this to simulations of the system response. During post-test analysis:

- Both measured levels of damping and computer-based damping analysis must demonstrate acceptable damping stability results.
- The test team must determine whether system 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, the test team will develop or refine procedures to adjust simulation parameters or simulation output to improve the representation of actual system damping.
- The test team will determine whether the dynamic response of the system is acceptable. This will be accomplished by comparing initial simulated system damping performance against measured damping performance and assessing the degree of agreement between the two sets of results remains within tolerance taking into account offsets between modelled and simulated damping performance. Where necessary, discrepancies between the actual and simulated system behaviour will be investigated. The test team will evaluate the materiality of such discrepancies to determine potential impact on progression of testing. There is confidence that the OSM provides an accurate view of system stability and it will be relied upon in confirming the acceptability or otherwise of the inter-network tests.
- Disturbance tests should align with simulated results, taking into account differences that may arise due to variation in system operational conditions during the test period, and the (sum) difference in computer models and the physical system.
- The transmission plant and generators control system performance must meet the expected performance.

At the conclusion of each test and based on the results of the offline test analysis and hold point reports by the project proponents, the AEMO-appointed Test Co-ordinator shall advise whether:

- Adequate online measurement data is available to identify the level of damping at the test level;
- Damping levels observed via OSM during the test were within the expected range; and
- A test at a higher transfer level may be scheduled, subject to power system security.

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

In order to streamline the movement between hold points, and to avoid missing testing opportunities, it may be possible to use the analysis of the outcomes of one test (the post-test analysis) as the pre-test simulations for the next test. This will depend on whether system conditions have changed significantly after a specific hold point test.

11.4 Increased power transfer test hold points

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 which will result in the total number of tests 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.

12 Impact on participants' plant

12.1 Generic system damping assessment

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.

12.2 Disturbance/switching tests

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.

13 Participant communication

This test program will be published on the AEMO website in accordance with clause 3.13.13 of the Rules. Tests may only commence after 20 business days from publication of the final test program.

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

During active testing, a Market Notice will be issued to advise when a series of tests will be conducted. 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 test 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 AEMO, Transgrid, ElectraNet and AVP and a final Market Notice will be issued by AEMO to advise when the interconnector capability (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.

Appendix A. Test Process Charts

Figure 2: Process for moving between hold points

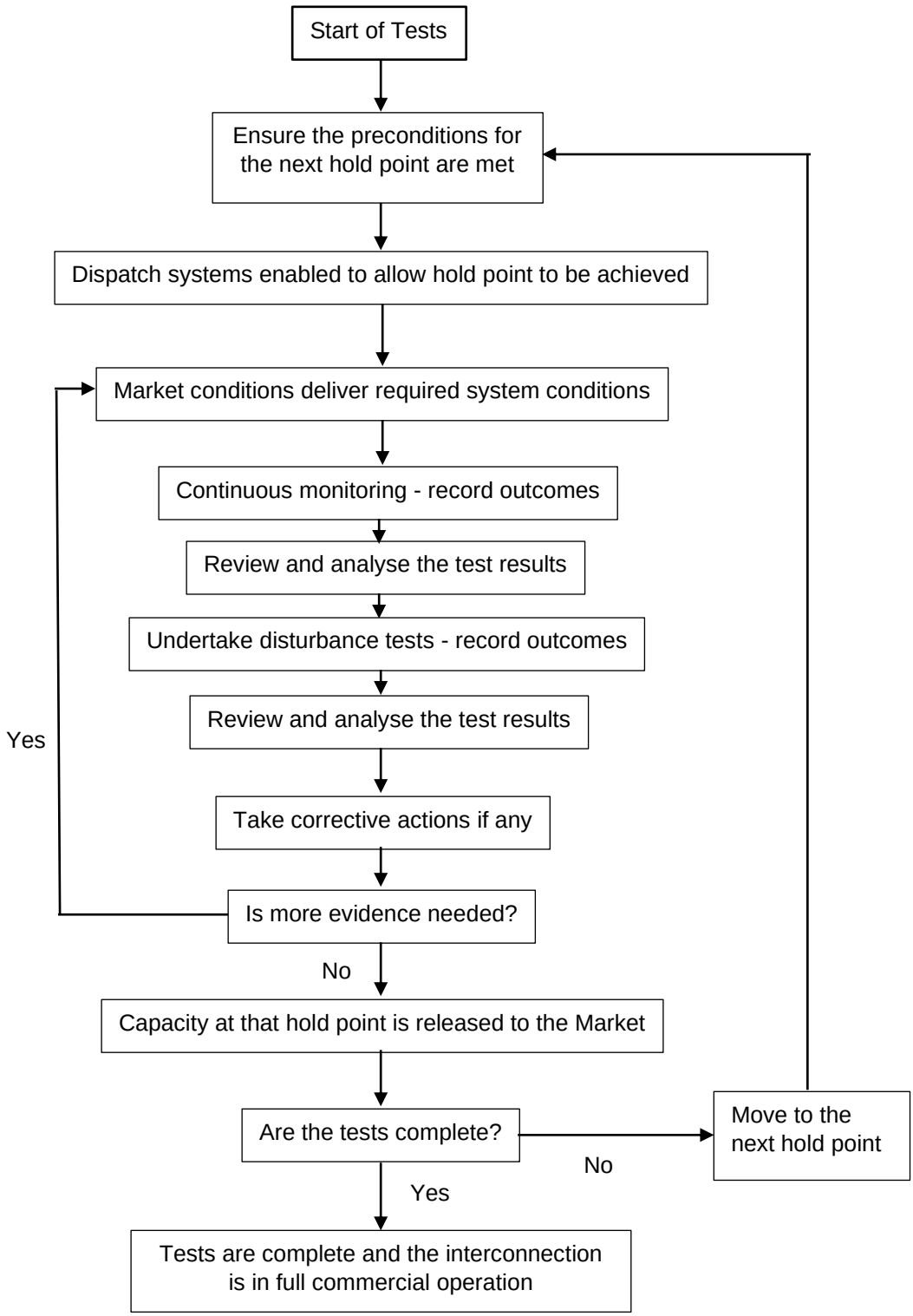
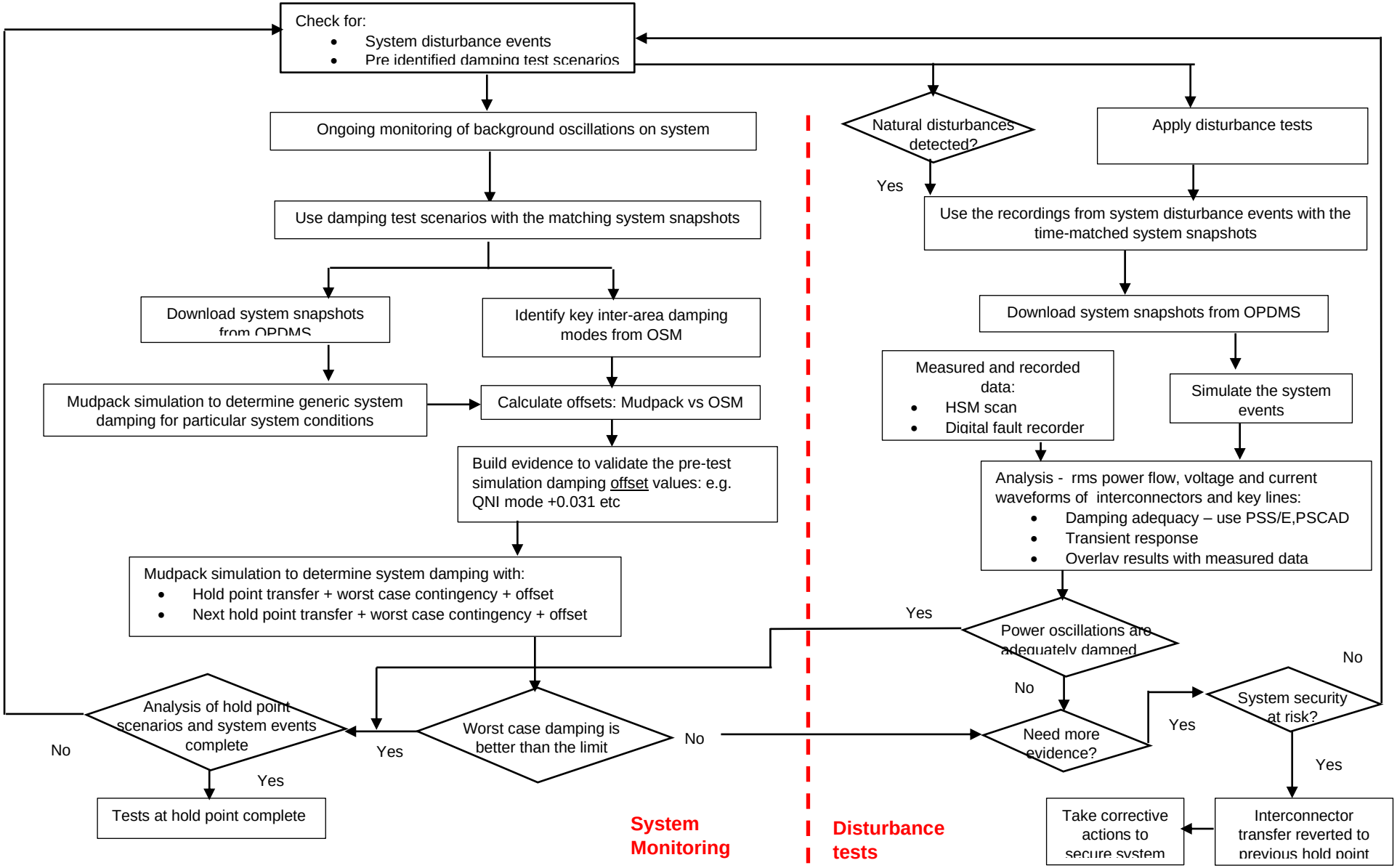


Figure 3: Analysis process



Appendix B. 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.

B1 High Speed Monitors (HSM) and Phasor Monitoring Units (PMU)

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

Existing HSMs in NSW, Victoria and SA and new HSMs installed for PEC may be used to monitor and record inter-network test results. The selection of which HSMs will be used for specific tests will be determined through further analysis.

A new Wide Area Measurement Scheme is being installed in SA and this facility may be used in the testing.

AEMO, Transgrid, ElectraNet and AVP will analyse HSM recordings.

Continuous slow scan 50 Hz data are stored for two weeks. A number of the HSMs are configured to trigger a slow scan data recording automatically for network disturbances. Some HSMs are configured to OPDMS system so that 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 Digital fault Recorders (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 second and 4 seconds respectively. The sampling rate should be in excess of 64 samples per cycle.

B2 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.

At present 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. AEMO will confirm the PhasorPoint system is functioning prior to conducting a test.

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, LOR conditions and line reclassifications etc.

AEMO logs include high-level event descriptions which can be sorted by region and time.

B3 Identifying damping test scenarios

AEMO and the proponents will use their existing tools to view forecast of regional demand, interconnector flows, wind forecast and reserve data etc to identify suitable scenarios for testing.

B4 Other systems

In addition, it expected that AEMO, ElectraNet,Transgrid and AVP 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.

Appendix C. Project proponents

Table 3: PEC proponents

Company	**Role**
ElectraNet	Proponent
Transgrid	Proponent

Table 4: HIC Proponents

Company	**Role**
ElectraNet	Proponent
AEMO Victorian Planning	Proponent