

COMMISSIONING REQUIREMENTS FOR GENERATING SYSTEMS

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1 Purpose of Document

This document presents the approach of the Australian Energy Market Operator (AEMO) to the commissioning of plant in a generating system. It aims to assist connection applicants and Network Service Providers (NSPs) to understand the principles, processes, information requirements and issues considered by AEMO when commissioning generating systems. The commissioning process described applies to all generators seeking to register or operate in the NEM (National Electricity Market), and applies to all types of generating systems.

This document is not intended to prescribe commissioning practice for generators commissioning their generating systems nor to describe how generators can demonstrate compliance with their own performance standards. Therefore, the tests listed in this document are not exhaustive and do not include all tests that may be required for generators undertaking their commissioning of generating systems.

2 AEMO's Roles in Commissioning

AEMO's roles in relation to commissioning include:

- operator of the power system and responsible for power system security across the NEM;
- operator of the electricity trading market; and
- provider of declared network functions in specified jurisdictions.

As the system operator, AEMO becomes involved in the commissioning of all new registered plant connected to the distribution network, and all new plant connected to the transmission network. In all states, AEMO reviews commissioning tests to ensure power system security is maintained. In these circumstances, AEMO consults with the relevant NSP to ensure that the generating system complies with the Registered Performance Standards through the commissioning process. Commissioning tests are undertaken to demonstrate the generating system meets the Registered Performance Standards, and to provide sufficient information to allow the generating system to remain online without direct supervision.

As the provider of declared network functions, AEMO acts as both system operator and the relevant NSP, and becomes more directly involved in the management of the commissioning process in the same manner as an NSP.

Where an existing generator is changing settings or replacing part or all of a generating system in such a way that it may impact on the Registered Performance Standards of the generating system, AEMO expects that the same commissioning process will apply. Commissioning tests may still be required if the replacement of part or all of the generating system is expected to deliver identical performance (i.e. like-for-like replacement).

Replacement equipment may include:

- machine winding changes (including stator and rotor rewinds)
- voltage control system or excitation system setting changes or replacement
- power control or governor control setting changes or replacement
- setting changes to dynamic reactive plant or replacement of parts of dynamic reactive plant that affect performance.

In all circumstances, AEMO's commissioning process assists AEMO in the management of system security issues during commissioning. The commissioning phase also and normally represents the commencement of model validation activities by the Generator.

3 Legal and Regulatory Framework

AEMO carries out its functions in accordance with the National Electricity Law (NEL) and the Rules. This includes rules relating to its operational and administrative functions for the NEM. AEMO has additional responsibilities under the NEL, where AEMO has been appointed as the provider of declared network functions in certain jurisdictions. At this time, AEMO has been appointed as the provider of declared network functions in Victoria.

4 Related Policies and Procedures

This document is related to other policies, procedures and guidelines produced by AEMO and should be read in conjunction with these other documents, as follows:

- Guidelines for Shared Transmission Connections
- Guidelines for Establishing Terminal Stations
- Active Management of Victorian Connection Applications
- Guidelines on Assessment and Acceptability Criteria Used for Generator Performance Standards

5 Principles

The commissioning of new or upgraded plant that interacts with the power system is an essential stage in the process of implementing a new connection. AEMO applies the same principles for the commissioning of all generating systems, regardless of technology type. The commissioning process is directly managed by the registered participant and the relevant NSP, generally in consultation with AEMO. As the first stage of the commissioning process, the applicant must develop a commissioning plan and submit the plan to the relevant NSP and AEMO.

For some technology types, particularly synchronous machines, many years of commissioning activities have resulted in a well understood range of commissioning tests that demonstrate a generating system's ability to remain safely connected to the power system.

For other technology types, industry experience is not well established and commissioning requirements are not fully developed. In these cases, commissioning requirements will depend on the capability and connectivity of the generating system, and AEMO will consider a range of commissioning tests to prove that the generating system complies with the Registered Performance Standards, and is safe to remain connected to the power system.

The overall approach to commissioning is outlined in Clause 5.8 of the Rules. In particular, the generator is required to cooperate with the relevant NSP and AEMO to ensure that commissioning is undertaken in a manner that:

- does not adversely affect other registered participants;
- does not affect power system security or quality of supply; and
- minimises the risk of damage to the equipment of other registered participants.

The applicant is responsible for specifying and undertaking commissioning tests and providing evidence to AEMO and the relevant NSP that demonstrates the performance of the plant. The commissioning tests of interest to AEMO are considered a part of the overall commissioning activities, with AEMO expecting that the applicant would have additional commissioning requirements.

General principles applied for the commissioning of generating systems across the NEM are:

- Commissioning tests are intended to provide evidence to AEMO and the NSP at the time of commissioning that a generating system may remain safely connected to the power

system, and the generating system meets the Registered Performance Standards and any other technical requirements specified in the connection agreement.

- AEMO requires the applicant to compare the actual recorded results with the results expected from design or modelling. Once a model is verified under one set of conditions, it is assumed to be verified for other sets of conditions in the model.
- Independent equipment is to be installed to collect commissioning results separate from the device under test; and the resolution and accuracy of the test instruments, for both time and recorded value, are suitable to measure the response.

6 Demonstration of Performance Standards

During commissioning, the applicant must demonstrate that its generating system meets or exceeds the Registered Performance Standards. Wherever practicable, the performance of the generating system must be demonstrated by test. However, these tests cannot demonstrate that the performance of the generating system meets the performance standards for all system conditions. Indeed, there are some performance standards that cannot be demonstrated by test.

To robustly demonstrate the performance of the generating system against all performance standards, AEMO requires that commissioning tests demonstrate that the actual plant performance meets the expected plant performance within predefined and agreed tolerances.

Commissioning tests are undertaken under power system conditions at the time of commissioning; however, the comparison of actual results against the design or modelled results provides reasonable evidence that the generator may remain in service for the full range of power system conditions according to its design.

Table 1 outlines those performance standards, for which AEMO expects the applicant to design practical on-site commissioning tests.

Table 1: Performance Standards Evidenced by On-Site Testing

Rules reference	Performance standard	Demonstrated on-site
S5.2.5.1	Reactive power	Partially ¹
S5.2.5.2	Quality of electricity generated	Yes
S5.2.5.3	Response to frequency disturbance	Partially ²
S5.2.5.4	Response to voltage disturbance	Partially ²
S5.2.5.5	Response to contingency event	Partially ²
S5.2.5.6	Quality of electricity generated and continuous uninterrupted operation	Yes
S5.2.5.7	Partial load rejection	Partially ³
S5.2.5.8	Protection from power system disturbance	Yes
S5.2.5.9	Protection system that impact on power system security	Yes
S5.2.5.10	Protection to trip plant for unstable operation	Yes
S5.2.5.11	Frequency control	Partially ⁴

S5.2.5.12	Impact on network capability	No
S5.2.5.13	Voltage and reactive power control	Partially ⁵
S5.2.5.14	Active power control	Yes
S5.2.6	Monitoring and control requirements	Yes
S5.2.7	Power station auxiliary supplies	Yes
S5.2.8	Fault current	No

Notes to table:

1. The reactive power range may be demonstrated on-site at various active power outputs, but is unlikely to be demonstrated for the full voltage range.

2. The actual response to frequency and voltage disturbances and the actual response to contingency event is unlikely to be demonstrated on-site; however, the limits of the protection systems that impact on this performance standard may be demonstrated.

3. The actual performance of the generating system for the loss of a major part of the transmission system may not be demonstrated on-site. The performance of the generating system may be partially demonstrated through partial or full load rejections or large frequency step responses.

4. The actual performance of the generating system during frequency variations is unlikely to be demonstrated on-site. The ability of the generating system to remain connected may be partially demonstrated through testing of the protection systems.

5. The actual performance of the generating system during all oscillations under all system conditions is unlikely to be demonstrated on-site. The performance of the generating system may be partially demonstrated through model validation.

Appendix A and Appendix B each outlines a number of typical tests that have been conducted on generating systems in the past. These tests are not mandatory; however, the results from these tests have been used in the past to demonstrate generating system performance.

The generator must advise AEMO that the generating system is able to comply with each of the Registered Performance Standards.

If the results show a failure to meet a generating system's Registered Performance Standard or model, an NSP may advise AEMO not to proceed with commissioning, or otherwise constrain the output of the generator if there is a risk of damage to the power system, a risk to system security, or other safety concerns. Where the generating system is connected and acts inconsistently with its Registered Performance Standards at commissioning, AEMO may also constrain the output of the generating system to any output (including zero), or otherwise disconnect the plant.

6.1 Hold Points

AEMO will nominate specific points in the commissioning plan, at which the generator must submit results for AEMO to review prior to progressing further with commissioning. Broadly, AEMO may require the applicant to submit commissioning test results prior to synchronisation occurring and through a staged release of capacity. This process allows the demonstration of Registered Performance Standards through testing at various pre-agreed output levels. Typically, hold points will be established at minimum load, and 50% and 75% of maximum output of the generating system or generating unit.

7 Developing a Commissioning Plan

As the first stage of the commissioning process, the applicant must develop a commissioning plan and submit the plan to both the relevant NSP and AEMO. The commissioning plan must be submitted at least three months prior to when commissioning is expected to take place for a

transmission connected generating system and a minimum of one month prior to when commissioning is expected to take place for a distribution connected generating system.

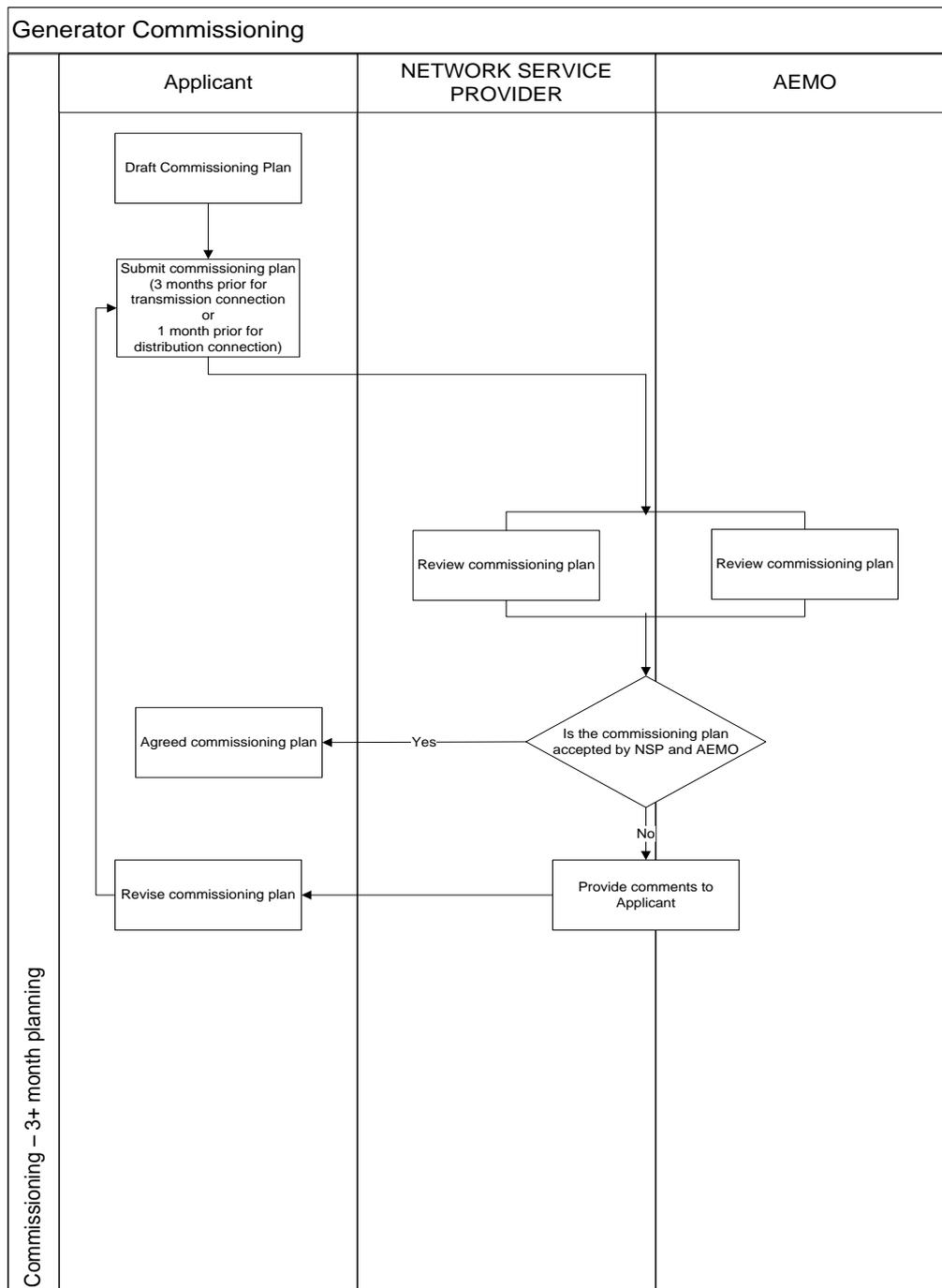
The plan is then reviewed by both the relevant NSP and AEMO. AEMO may also request further information in relation to the proposed plan, including test procedures or data capture and storage methods.

If either the relevant NSP or AEMO identifies any concerns, the parties will negotiate changes to the commissioning plan until a final plan is agreed.

AEMO and the NSP must notify the registered participant that they agree with the proposed commissioning plan, or require changes to it in the interest of maintaining power system security, safety of operation, and quality of supply.

Figure 1 outlines the interactions between the Applicant, the relevant NSP and AEMO within this process.

Figure 1 - Interaction between Applicant, relevant NSP and AEMO for drafting of commissioning plan



7.1 Commissioning Test Plan Requirements

The Rules do not detail any specific commissioning tests that must be undertaken by a registered participant. Instead, as technologies, types and the specific installation (either in installed equipment or settings) may vary from site to site, it is expected that the tests will be tailored to the requirements of the installed equipment and settings.

The commissioning plan must include a list of commissioning tests to be undertaken, providing:

- a description of the purpose of the test, outlining:
 - the equipment under test;
 - which performance standard will be assessed;
 - what comparison against model will be assessed;
- the proposed dates and durations for the tests;
- measurement equipment; and
- any specific network conditions.

The plan must allow for hold points and include a proposal for evidence to be provided at each hold point.

The commissioning plan may include other commissioning tests; however, it must show clearly which tests are intended to demonstrate the performance of the generating system against the Registered Performance Standards.

AEMO may request a specific commissioning test procedure for further clarity regarding a particular test.

7.2 Commissioning Tests and Registered Data

As part of either the establishment of a new generating system or the replacement of plant within an existing generating system, there are registered data values that must be submitted to AEMO in two stages.

The first stage, resulting in category R1 data, occurs prior to registration and commissioning.

Within three months of the completion of commissioning, an applicant is required to submit updated data values from on-site tests for specific data items, resulting in category R2 data. These data items are identified through the Generating System Design Data Sheets and Generating System Setting Data Sheets¹.

This document does not cover the process or testing requirements for R2 data validation. Process and testing requirements for R2 data validation may be issued by AEMO in a related document at a later date. Test results from the commissioning tests, however, may provide or contribute to R2 data values.

7.3 Undertaking Commissioning

7.3.1 Preconditions to Online Commissioning

Prior to commencing online commissioning of a generating system, the following must be completed:

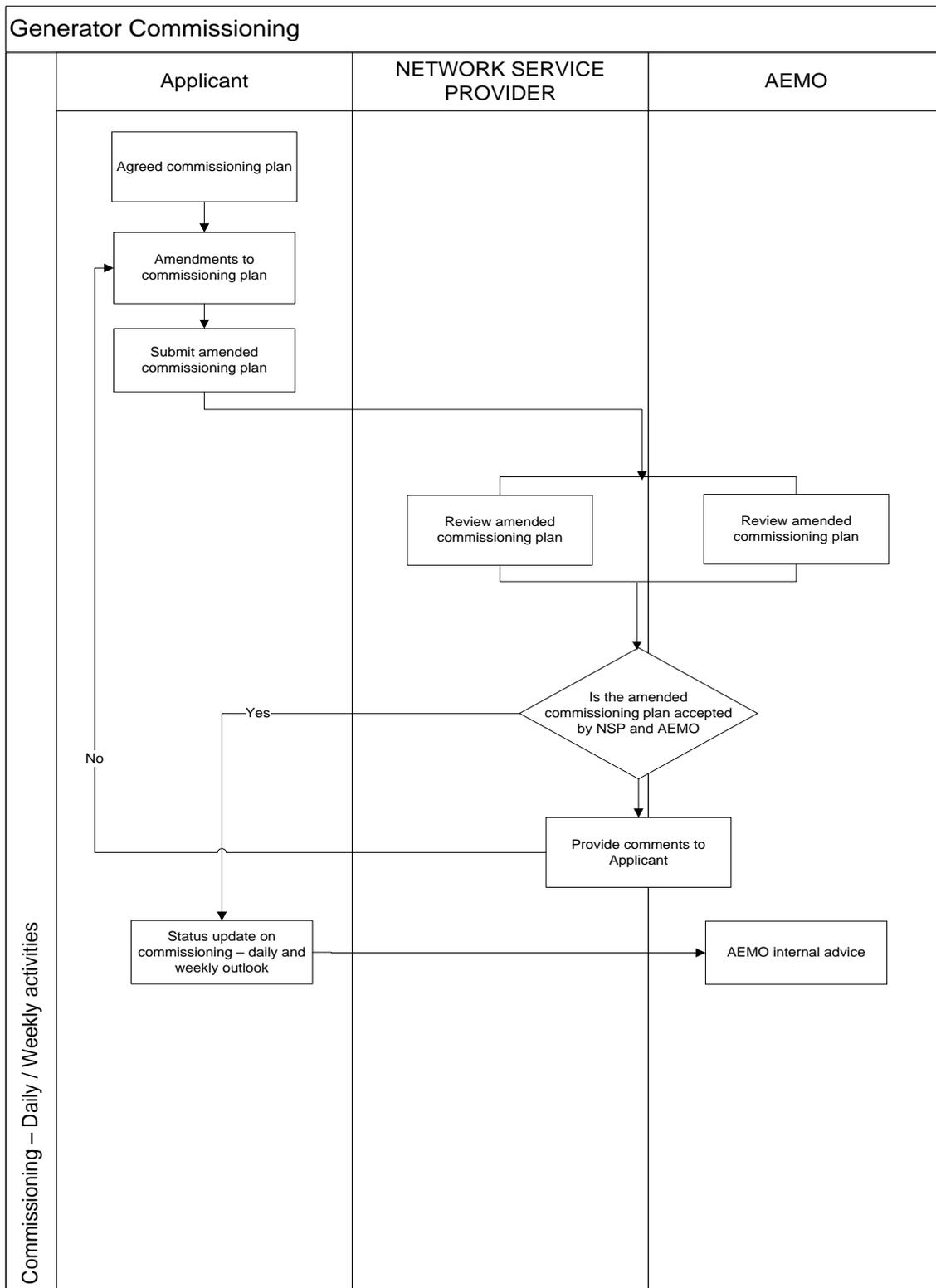
- approval of commissioning plan for the generating system;
- registration of the generating system; and
- commissioning of SCADA systems relating to the generating system.

¹ <http://www.aemo.com.au/registration/118-0001.html>

7.3.2 Provision of Commissioning Status Advice

As commissioning activities may be subject to rescheduling due to on-site works and issues, AEMO may request that the applicant provide regular updates regarding commissioning. These updates may be requested on a weekly or daily basis depending on the impact of the generating system on the power system. This status advice may also provide an opportunity to review and update the commissioning plan. Figure 2 below outlines the process for the provision of status advice.

Figure 2 - Daily and weekly update process for commissioning testing



7.3.3 Undertaking a Commissioning Test

As commissioning activities may impact on the power system or the NEM, specific actions may be required prior to undertaking online commissioning tests. For these tests, AEMO requires that the applicant:

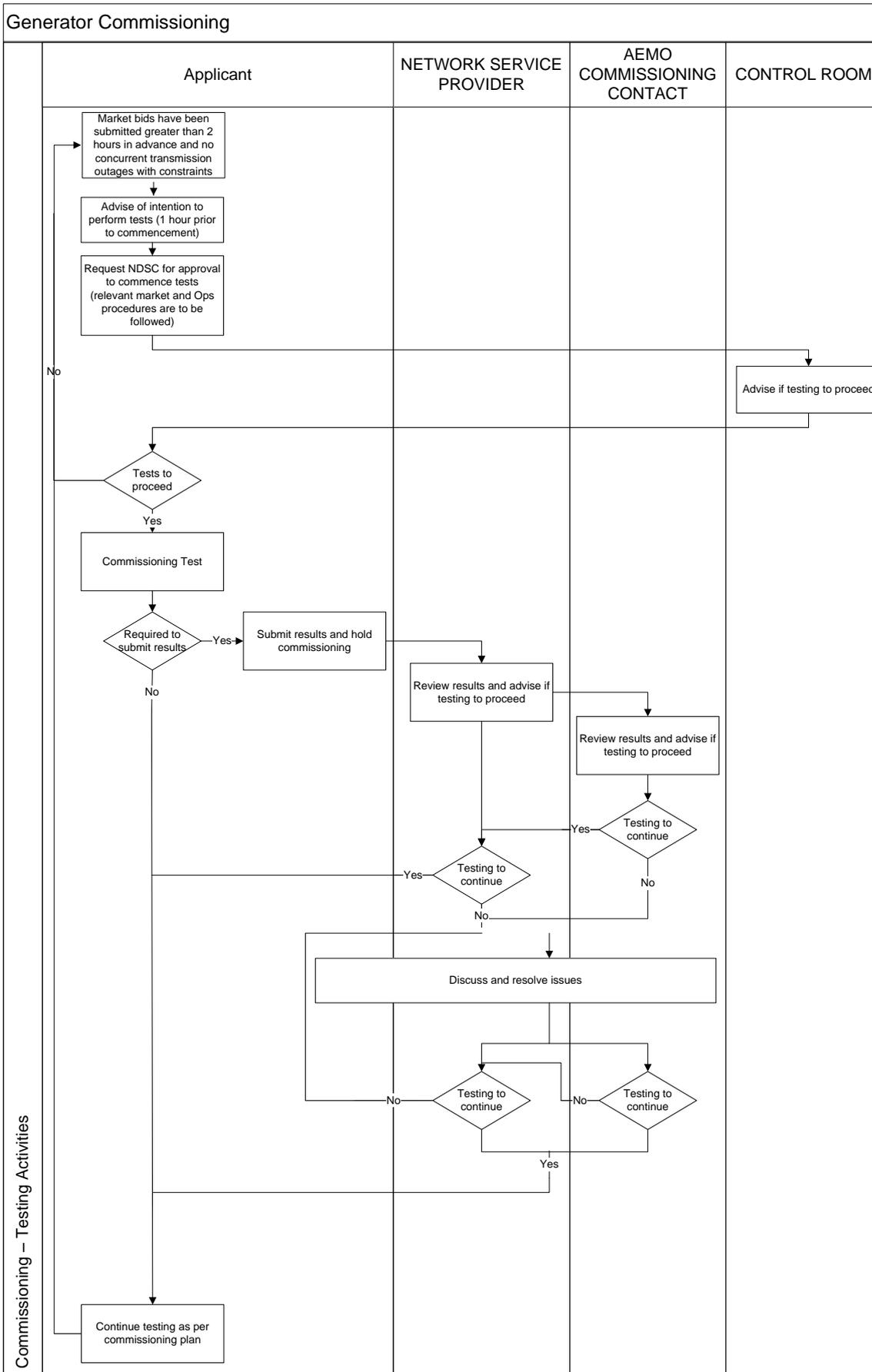
- advise appropriate contact details in advance of commissioning;
- contact the AEMO control room prior to commencing a commissioning test that may impact:
 - the MW, MVar, voltage or frequency of the generating system; or
 - has the potential to impact the performance of the generating system as outlined in the Registered Performance Standards;
- follow all appropriate operational and market protocols including:
 - complying with the requirements set out in section 9 of the published guidelines in relation to power system security²;
 - reflecting its proposed commissioning activities in the electricity market systems;
 - submitting all market bids no less than two hours prior to the commencement of any commissioning test.

The AEMO control room may, at its sole discretion and to manage power system security, require the delay or cancellation of a commissioning test due to system conditions at the time. In assessing the situation, AEMO will consider outages underway or planned to commence immediately after or during the commissioning test.

Figure 3 outlines the process for undertaking a specific commissioning test.

² <http://www.aemo.com.au/electricityops/3715.html>

Figure 3 - Interaction between Applicant, relevant NSP, AEMO and AEMO Power System Operations during a commissioning test



Commissioning – Testing Activities

7.4 Commissioning Results

During the preparation of the commissioning plan AEMO will nominate any tests that need to be reviewed prior to undertaking further testing and any other test results that need to be submitted as they become available.

The output of the generating system will be constrained and testing will not be permitted at higher output levels until a review of the commissioning test results is completed. Once AEMO has reviewed the commissioning test results for each hold point, AEMO will allow the generating system to progress beyond that hold point.

7.5 Commissioning Report

A draft commissioning report must be submitted to AEMO no more than three months after the completion of commissioning. This commissioning report must:

- outline the commissioning tests undertaken on-site;
- compare expected performance (modelled) with on-site performance; and
- outline the conclusions drawn regarding compliance with the NER, compliance with the design and consistency with the model.

7.6 Compliance Programs

Once commissioning of the generating system is complete, the applicant must establish a compliance program in accordance with Clause 4.15 of the Rules. Under the current arrangements, AEMO and NSPs no longer have a role in establishing generator compliance programs.

The Reliability Panel has established a template for generator compliance programs³.

³ <http://www.aemc.gov.au/Market-Reviews/Completed/Template-for-Generator-Compliance-Programs.html>

Appendix A: Typical tests for synchronous machines

To assist the applicant with the preparation of a commissioning plan, Table A1 outlines a number of typical tests that have been conducted on synchronous machines in the past. These tests are not mandatory; however, the results from these tests have been used in the past to demonstrate Registered Performance Standards.

Table A1: Typical tests for synchronous machines

Performance Standard	Offline tests	Online tests
S5.2.5.1	Not applicable	Vee Curve Tests Capability Curve Tests Online step response tests (into limiters)
S5.2.5.2	Quality of supply monitoring	Quality of supply monitoring
S5.2.5.3	Secondary injection testing	On load protection tests
S5.2.5.4	Secondary injection testing	On load protection tests
S5.2.5.5	Secondary injection testing	On load protection tests
S5.2.5.6	Secondary injection testing	On load protection tests
S5.2.5.7	Not applicable	Online step response tests Full load rejection Partial load rejection
S5.2.5.8	Secondary injection testing	On load protection tests
S5.2.5.9	Secondary injection testing	On load protection tests
S5.2.5.10	Secondary injection testing	On load protection tests
S5.2.5.11	Offline step response test	Online step response tests Partial/Full load rejection
S5.2.5.12	Transfer function tests Model validation tests	Model validation tests Online step responses
S5.2.5.13	Transfer function tests Offline step response tests Open circuit saturation curve V/f limiter tests	Online step response: under excited unity power factor over excited into limiters
S5.2.5.14	Not applicable	Response to dispatch instructions Online step response tests

Performance Standard	Offline tests	Online tests
S5.2.6	SCADA commissioning tests	SCADA commissioning tests
S5.2.7	Quality of supply Power factor tests	Quality of supply Power factor tests Online protection tests
S5.2.8	Not applicable	Not applicable

AVR and PSS Transfer Function Measurement Requirements

To enable confirmation of AVR and PSS models from test, onsite transfer function measurements will be required. This is expected to be done through the injection of a sinusoidal signal (or swept sine signal) into the front end of the AVR or PSS, with the output recorded for gain and phase calculations.

This will measure the transfer function between the AVR input and output (or PSS input and AVR output in turn). The transfer function from the AVR output to the rotor voltage will also be required to be measured. This is expected to be done once the generator is excited and at normal speed.

For digital AVRs, it is usually necessary to use A-to-D and D-to-A converters to interface to the required signals, and also to provide input to the AVR.

The transfer functions provided will need to be in the form of Bode plots (gain and phase), over the frequency range 0.05–10 Hz, with at least 14 points per frequency decade, preferably with averaging to reduce the effects of noise interference.

Appendix B: Typical tests for other than synchronous machines

To assist the applicant with the preparation of a commissioning plan, Table B1 outlines a number of typical tests that have been historically conducted on devices other than synchronous machines. These tests are not mandatory; however, the results from the tests have been used in the past to demonstrate Registered Performance Standards.

Table B1: Typical tests for other than synchronous machines

Performance Standard	Offline tests	Online tests
S5.2.5.1	Not applicable	Operation at reactive power limits
S5.2.5.2	Quality of supply monitoring	Quality of supply monitoring
S5.2.5.3	Secondary injection testing	On load protection tests
S5.2.5.4	Secondary injection testing Model validation tests	On load protection tests Model validation tests
S5.2.5.5	Secondary injection testing	On load protection tests
S5.2.5.6	Secondary injection testing	On load protection tests
S5.2.5.7	Not applicable	Not applicable
S5.2.5.8	Secondary injection testing	On load protection tests
S5.2.5.9	Secondary injection testing	On load protection tests
S5.2.5.10	Secondary injection testing	On load protection tests
S5.2.5.11	Offline step response tests to determine frequency control Model validation tests	Online step response tests to determine damping performance Model validation tests
S5.2.5.12	Model validation tests	Model validation tests
S5.2.5.13	Model validation tests	Online step response tests at various generation and reactive power levels including into any limiters
S5.2.5.14	Not applicable	Response to dispatch instructions Online step response tests
S5.2.6	SCADA commissioning tests	SCADA commissioning tests
S5.2.7	Quality of supply Power factor tests	Quality of supply Power factor tests Online protection tests
S5.2.8	Not applicable	Not applicable

