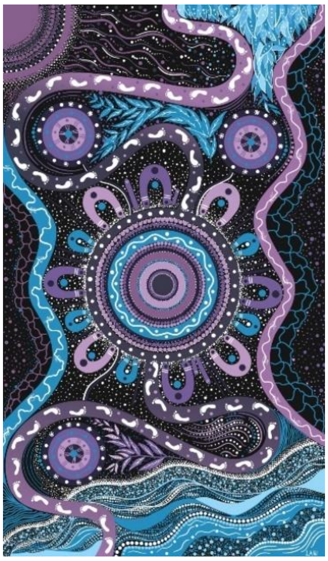
AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

System Strength Impact Assessment Guideline Withstand SCR Methodology Review

February 2025

Technical note on assessing power transfer limits

Version 2.1



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We acknowledge that, wherever we work, we do so on Aboriginal and Torres Strait Islander lands. We pay respect to the world's oldest continuing culture and First Nations peoples' deep and continuing connection to Country; and hope that our work can benefit both people and Country.

'Journey of unity: AEMO's Reconciliation Path' by Lani Balzan

AEMO Group is proud to have launched its first Reconciliation Action Plan in May 2024. 'Journey of unity: AEMO's Reconciliation Path' was created by Wiradjuri artist Lani Balzan to visually narrate our ongoing journey towards reconciliation - a collaborative endeavour that honours First Nations cultures, fosters mutual understanding, and paves the way for a brighter, more inclusive future.

Important notice

Purpose

AEMO has prepared this document to understand the limitations of the current System Strength Impact Assessment Guidelines (SSIAG) test methodology for assessing the withstand short circuit ratio (SCR). Clarifications and adjustments have been proposed to ensure that the methodology does not prescribe test conditions for plant that result in a breach of active power transfer limits in weak grid conditions.

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Version control

Version	Release date	Changes
#1.0	02/07/2024	Initial draft
#1.1	23/08/2024	Editorial updates – first public release
#2.0	13/12/2024	Updated draft version, incorporating updates: • Explanation of requirement for dQ/dV $\geq$ 0 (section 1.2) • Updated guidance on infinite bus voltage setpoint (section 3.3) • Clarification on definition of Prated (section 4.2) • Clarification on suggested treatment of IBL (section 4.3) • Addition of tables with proposed tests (section 5) • Other editorial updates
#2.1	28/02/2025	Moved definition of P_{lookup} to first occurrence and other editorial updates

Abbreviations

Abbreviation	Term
3PHG	Three-phase to ground
AEMO	Australian Energy Market Operator
AFL	Available Fault Level
BESS	battery energy storage system
EMTDC™	electromagnetic transient including DC
GFL	Grid-following
GFM	Grid-forming
IBL	Inverter-based load
IBR	Inverter-based resource/s
OEM	original equipment manufacturer
MVA	megavolt ampere/s
MVAr	megavolt ampere/s reactive
MW	megawatt/s
NEM	National Electricity Market
NER	National Electricity Rules
NSP	network service provider
OEM	original equipment manufacturer
PSCAD™	Power System Computer Aided Design
PSS®E	Power System Simulator for Engineering
pu	per unit
SCR	short circuit ratio
SMIB	Single Machine Infinite Bus
SSC	System Strength Charge
SSIAG	System Strength Impact Assessment Guidelines
SSQ	System Strength Quantity

Executive summary

The System Strength Impact Assessment Guidelines (SSIAG[1]) introduced new concepts and methodology to evaluate the impact of inverter-based resource (IBR) generators and loads on the system. AEMO is required to publish the SSIAG under National Electricity Rules (NER) 4.6.6 which includes a requirement to provide a methodology for assessing the short circuit ratio (SCR) to determine whether a connecting plant complies with the SCR access standards[2].

The minimum set of Withstand SCR tests for a 4.6.6 Connection is specified in Appendix B of the SSIAG. The tests are intended to assess the plant's capability to ride through low SCR scenarios (down to an SCR of 1.2 as defined by the stability coefficient constant value). This assessment must take into account power transfer limits at the connection point, as required by the acceptance criteria in SSIAG sections 7.4.4 (h) and (i). As currently defined, the tests do not contemplate active power absorption by connecting plant. This represents a gap in the current SSIAG methodology which results in plant being incapable of simultaneously satisfying the requirements of the acceptance criteria in sections 7.4.4 (h) and (i) while operating at full rated charging levels as required by section 7.4.3 (d).

This document focuses on clarifying and adjusting the Withstand SCR tests to accommodate conditions where connecting plant is absorbing active power without breaching power transfer limits at the connection point, with the aim of giving effect to the intent of the current SSIAG methodology when applied to power absorbing plant.

In this review, AEMO proposes clarifications and adjustments to the Withstand SCR test methodology, for scenarios where the power transfer limits are breached or are likely to be breached. These clarifications and adjustments are based on static stability theory, that applies irrespectively to the plant mode of control (for example, grid-following or grid-forming).

The analysis presented in this technical note indicates that, for a given SCR, the power transfer limit that applies when the plant is in absorbing mode is more onerous than when the plant is in injection mode. As it stands, it is not possible for plant absorbing active power from the network (including grid-forming BESS) to achieve a withstand SCR of 1.2 when absorbing at its maximum rated power, because the methodology leads to a violation of power transfer limits. The recommendations are:

- **All plant** – AEMO proposes clarifying and adjusting the SSIAG methodology to define the infinite bus voltage instead of the fixed reactive power and voltage values at the plant connection point and expand on the minimum set of tests. The recommendation is to set the infinite bus voltage to 1.05 pu, include additional tests for unbalanced faults and reduce the fault duration for deep voltage dips.
- **Bi-directional plant operating in active power absorption mode (BESS, variable speed pumped hydro or hybrid plants)** – AEMO proposes clarifying and adjusting the SSIAG methodology to reduce the maximum active power flow, to avoid breaching power transfer limits at the connection point, based on the site-specific SCR and X/R ratio.

[1] AEMO, *System Strength Impact Assessment Guidelines*, Version 2.2, 28 June 2024, at https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2024/ssiag/system-strength-impact-assessment-guidelines-v22.pdf.

[2] NER S5.2.5.15, S5.3.11 and S5.3a.7.

- **Inverter-based load (IBL)** – AEMO recognises similar issues exist for IBL as the industry is still building its knowledge and experience with IBL technology. AEMO's review of technical requirements[3] proposes a detailed review of large loads, which began in October 2024. In the meantime, AEMO proposes IBL Withstand SCR assessment be treated in a similar way as bi-directional plant operating in active power absorption mode. AEMO will review and consider adjustments to the assessment method on a case by case basis until a revised method is developed.

Background

Section 7.4 of the SSIAG outlines how the SCR (referred to as Withstand SCR in the SSIAG) is to be assessed through dynamic simulation studies in a Single Machine Infinite Bus (SMIB) environment using site-specific Power System Computer Aided Design (PSCAD™)/electromagnetic transient including DC (EMTDC™) and Power System Simulator for Engineering (PSS®E) models.

The resultant Withstand SCR is used in determining the reduction in Available Fault Level (AFL)[4] caused by the connection of plant at its connection point, and to calculate the System Strength Quantity (SSQ)[5].

The published methodology for assessing the Withstand SCR takes into consideration the network conditions at the plant connection point and the technology of the plant being connected to define the acceptance criteria that should be applied.

The minimum set of tests to be carried out is described in Appendix B of the SSIAG. These tests require the plant to ride through three-phase to ground (3PHG) faults, impulse voltage steps and changes in network impedances with the network impedances varying from an equivalent SCR of 10 down to withstand SCR, irrespective of the plant's control mode (grid-following or grid-forming). Currently, Withstand SCR test requirements do not specify the infinite bus voltage and the active power absorption level for bidirectional plants.

Summary and way forward

The minimum withstand SCR tests as they stand in the current SSIAG make it impossible for any plant, which absorbs active power from the network, to achieve a withstand SCR of 1.2 at maximum power absorption due to a violation of power transfer limits at the connection point.

To demonstrate the power transfer limits under conditions where plant is absorbing active power, AEMO has used static stability theory. This theory is introduced in Section 1 of the technical note, and is the foundation of the static analysis in Section 2. It is important to highlight that from a static stability perspective, the technology or the control mode of the plant has no particular significance and any comparison of the dynamic stability of the grid-forming and grid-following technology is beyond the intent of this technical note.

The static stability limits have been verified through dynamic simulations performed in PSCAD™ (see Section 3), with recommendations outlined in Section 4. Key recommendations are to limit the plant's active power absorption in low SCR conditions based on the X/R ratio, and define the voltage of the infinite bus of the test network for the Withstand SCR tests rather than specify the reactive power and voltage values at the connection point. AEMO has proposed the addition of

[3] See https://aemo.com.au/consultations/current-and-closed-consultations/aemo-review-of-technical-requirements-for-connection.

[4] SSIAG Section 3.4

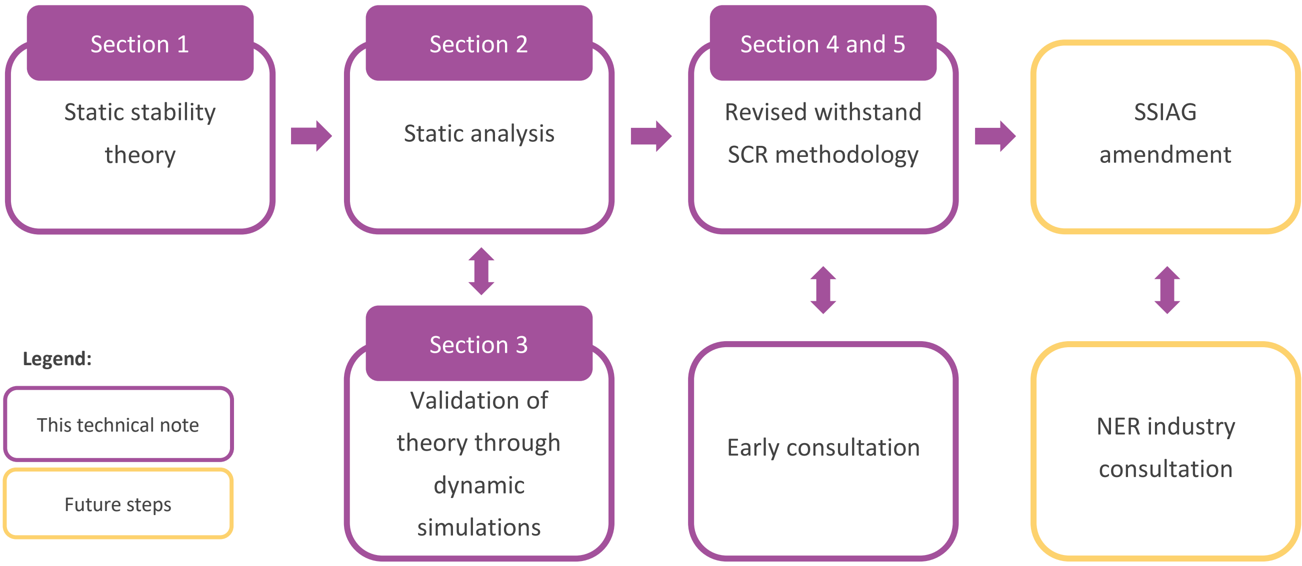
[5] NER 6A.23.5

unbalanced faults in the minimum set of grid fault test cases, and reducing the fault duration of deep voltage dips. Section 1 sets out an updated table of tests that addresses these issues and is intended to replace Appendix B of the SSIAG.

Figure 1 summarises the structure of this report and also sets out the proposed next steps to validate and implement the recommendations (in yellow). These next steps include early consultation with network service providers (NSPs) and industry stakeholders that have experienced the issue in the past, followed by broader industry consultation in line with the rules consultation procedures[6] to amend and publish an updated version of the SSIAG.

In the absence of clear guidance in the current SSIAG on the appropriate methodology to apply to plant that absorbs active power, AEMO encourages NSPs to consider adopting the principles of the methodology proposed in this technical note. This will assist in developing a consistent methodology across the NEM as compared with the variety of approaches which have been employed to date and will inform ongoing work to review and refine the SSIAG methodology in advance of future amendments to the SSIAG planned to commence in 2025.

Figure 1 Technical note structure and way forward



[6] NER 8.9

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1 Introduction

The System Strength Impact Assessment Guidelines (SSIAG[7]) introduced new concepts and methodology to evaluate the impact of inverter-based resource (IBR) generators and loads on the system.

As part of the SSIAG, AEMO is tasked under National Electricity Rules (NER) 4.6.6 to provide a methodology:

- To be used by network service providers (NSPs) for undertaking system strength impact assessments, and
- For assessing the short circuit ratio (SCR) to determine whether a connecting plant complies with the SCR access standards[8].

The Withstand SCR test cases for a 4.6.6 Connection are specified in Appendix B of the SSIAG. The tests are intended to assess the plant's capability to ride through low SCR scenarios, taking into account transfer stability limits according to the acceptance criteria in SSIAG sections 7.4.4 (h) and (i).

The Withstand SCR test cases contain three types of tests – three-phase to ground (3PHG) faults, voltage step changes, and impedance changes. The issues that are identified in relation to the tests are:

- For a given SCR, the power transfer limit that applies when the plant is in absorbing mode is more onerous than when the plant is in injection mode.
- Large initial positive reactive power injection from the plant is also necessary for the plant to absorb active power in weak grids.

In addition to the points listed above, and irrespective of whether the plant is generating or absorbing active power, the source voltage in the Single Machine Infinite Bus (SMIB) network is not specified for the SSIAG Appendix B test cases. It is, however, considered to be critical in determining the Withstand SCR.

The following section introduces the static stability theory that defines how much active power can be absorbed by inverter-based load (IBL), variable speed pumped hydro plants when in pumping mode and battery energy storage systems (BESS) when in charging mode. The theory is fundamental for the static case studies and analysis outlined in Section 2, demonstrating the influence of the SCR and X/R ratio on the power transfer limits.

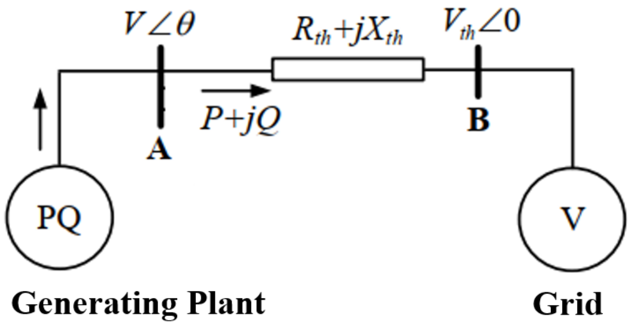
1.1 Static stability theory

The static stability theory is presented in a simplified two-bus system as shown in Figure 2, where the Generating Plant at Bus A is connected to Bus B (the infinite bus, voltage source) via an impedance of $R_{th}+jX_{th}$.

[7] AEMO, System Strength Impact Assessment Guidelines, Version 2.2, 28 June 2024, at https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2024/ssiag/system-strength-impact-assessment-guidelines-v22.pdf.

[8] NER S5.2.5.15, S5.3.11 and S5.3a.7

Figure 2 2-bus system for the static stability study



Equations (1) to (5)[9, 10] determine the *loci* for valid load flow solutions:

$$P = \alpha(V^2 - VV_{th}\cos\theta) + \beta VV_{th}\sin\theta \tag{1}$$

$$Q = \beta(V^2 - VV_{th}\cos\theta) - \alpha VV_{th}\sin\theta \tag{2}$$

where

$$\alpha = \frac{R_{th}}{|Z_{th}|^2} \tag{3}$$

$$\beta = \frac{X_{th}}{|Z_{th}|^2} \tag{4}$$

$$Z_{th} = \sqrt{R_{th}^2 + X_{th}^2} \tag{5}$$

If the grid impedance $R_{th}+jX_{th}$ is specified through a grid SCR and X/R ratio XRR ($=X_{th}/R_{th}$), then they can be calculated from Equation (6) to (8).

$$|Z_{th}| = \frac{1}{(SCR)} \tag{6}$$

$$R_{th} = \frac{|Z_{th}|}{\sqrt{1 + (XRR)^2}} \tag{7}$$

$$X_{th} = (XRR)R_{th} \tag{8}$$

[9] T. Lund, H. W., etc, *Operating Wind Power Plants Under Weak Grid Conditions Considering Voltage Stability Constraints.* IEEE Transactions on Power Electronics, vol. 37, no. 12, pp. 15482-15492, Dec 2022.

[10] A. Borićič, J. L. R. Torres and M. Popov, "Beyond SCR in Weak Grids: Analytical Evaluation of Voltage Stability and Excess System Strength," 2023 International Conference on Future Energy Solutions (FES), Vaasa, Finland, 2023, pp. 1-6, doi: 10.1109/FES57669.2023.10183286.

Equations (9) and (10) are for calculating ∂P/∂θ and ∂Q/∂V and can be derived from Equation (1) to (5).

$$\frac{\partial P}{\partial \theta} = VV_{th}(\alpha \sin\theta + \beta \cos\theta) \tag{9}$$

$$\frac{\partial Q}{\partial V} = 2\beta V - \frac{\frac{V_{th}^2 V}{|Z_{th}|^2} + 2P\alpha V - 2\alpha^2 V^3}{\sqrt{\frac{V_{th}^2 V^2}{|Z_{th}|^2} - (P^2 - 2P\alpha V^2 + \alpha^2 V^4)}} \tag{10}$$

The static stability theory requires the two-bus system to meet the ∂P/∂θ > 0 for angle stability and ∂Q/∂V > 0 for voltage stability simultaneously. It is important to note that the grid should have sufficient transfer capability to meet both ∂P/∂θ > 0 and ∂Q/∂V > 0 at the connection point under normal operating voltage, and thermal limits should also be satisfied.

In the two-machine system, the critical angle for power transfer capability is 90°[11] when considering angle stability. Note this relationship is mainly important when dealing with a two-machine system. For larger complex systems, an angular separation of 90° between two machines has no particular significance[12]. Nevertheless, both the voltage and angle stability limits define the power transfer capability, noting that voltage stability has a more significant impact than angle stability. This is demonstrated in the following sections.

1.2 Active power absorption issue

To better understand the issues with the 3PHG test methodology for conditions where a connection is absorbing power from the network (including variable speed pumped hydro pumping, BESS charging and IBL), the following basic test procedure is used:

1. Set the initial conditions at the connection point as P = -1.0 per unit (pu), Q = 0 pu and V = 1 pu.
2. Set the impedance of the network to achieve SCR of 10 and X/R of 3.
3. Set the network source voltage Vth = ~1.036 pu. This is the steady state source voltage for SCR of 10 and X/R ratio of 3 for the desired load flow.
4. Run the model until steady state is achieved and apply a 3PHG fault with a 0.43 second fault duration.
5. At fault recovery, the network impedance is adjusted to achieve SCR of 1.2 and X/R ratio of 3 post-fault.
6. Run the model until a new steady state is achieved, confirming the plant ride-through capability.

Independent of the technology type, the power transfer capability limit is breached if the connection point is fully absorbing (P = -1.00 pu) active power when the SCR is reduced to 1.2. The infinite bus voltage (V_{th}) is kept at the pre-fault initial conditions, which is V_{th} = 1.036 for this example. Sections 1.2.1 and 1.2.2 explain why the power transfer limit is breached.

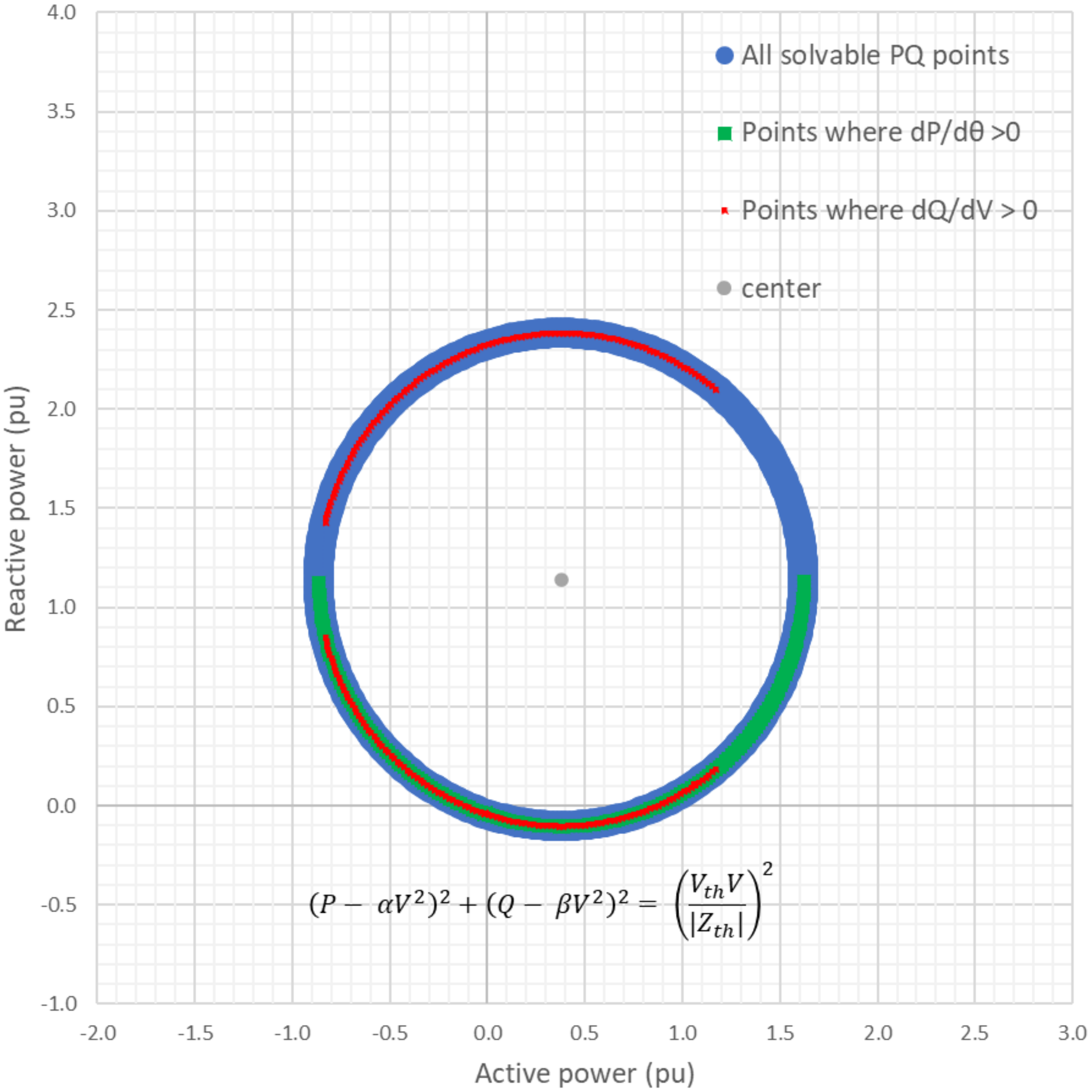
[11] The critical angle of 90° is only valid for pure reactive networks (X/R ratio >> ∞).

[12] Kundur, P. (1994), Power System Stability and Control.

1.2.1 Load flow loci

Figure 3 shows the load flow *loci* (in blue) and the limits of both angle and voltage stability for the conditions described above. The blue colour is a full circle that represents all solvable points that meet load flow Equations (1) to (8). The equation of the circle is shown in the figure which can be obtained by merging Equations (1) and (2). The green colour represents the part of the circle that satisfies ∂P/∂θ > 0, and the red colour is the part where ∂Q/∂V > 0. Only the part of the circle that have both green and red colours overlapped are solvable and statically stable. Therefore, only the PQ points on the bottom section of the red part are stable when V is controlled at 1.00 pu in a grid with SCR = 1.2, X/R = 3 and Vth = 1.036 pu. It shows that the maximum absorbing point (P = -1.00 pu) is unsolvable as it is not in the loci and hence stable operation is unachievable under theses system conditions. It is important to highlight that a similar effect would be encountered by an IBL.

Figure 3 Load flow solution loci for SCR 1.2, X/R = 3, V = 1.0 pu and Vth = 1.036 pu



1.2.2 Requirement for $\partial Q/\partial V \geq 0$

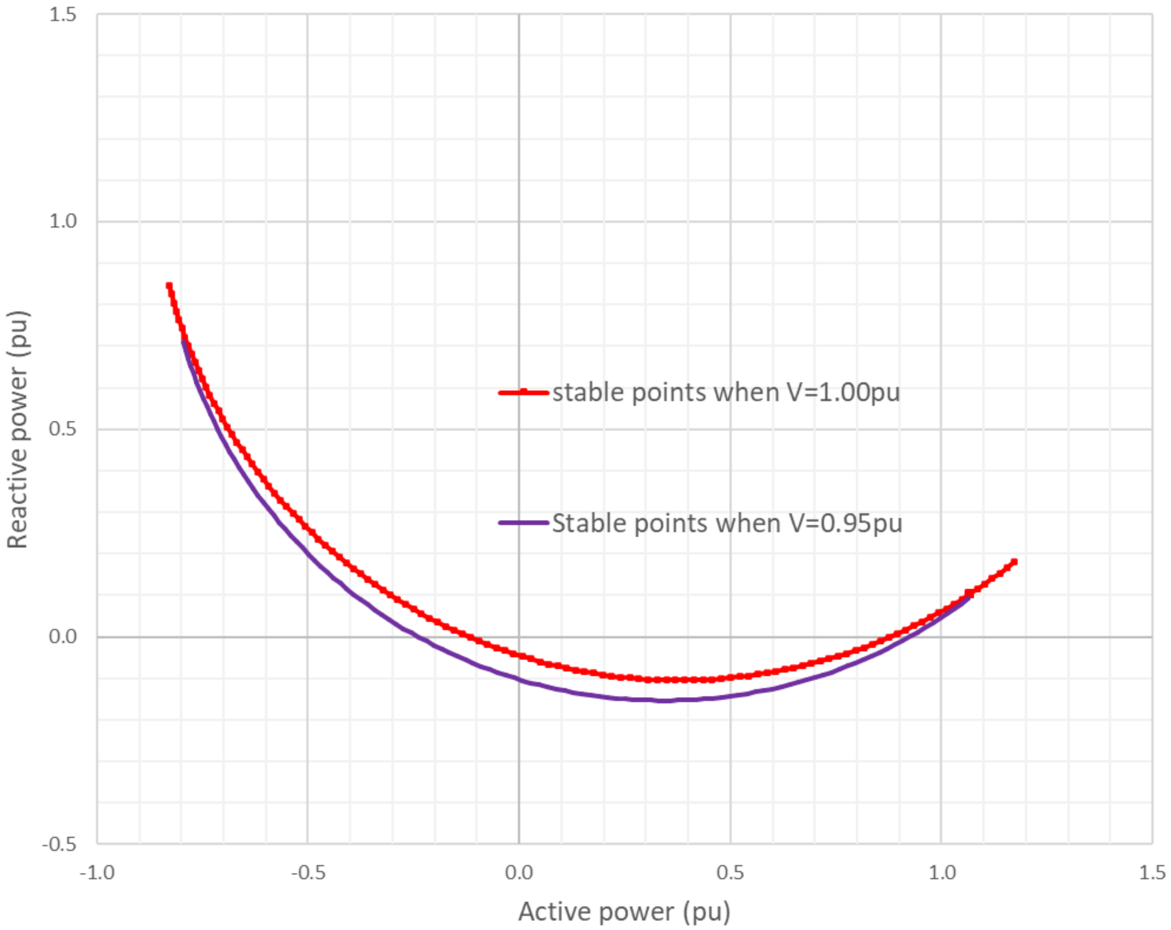
The requirement of $\partial Q/\partial V \geq 0$ is a key consideration in determining power system active power transfer limits. Figure 4 compares the stable parts of the PQ loci for plant connection point voltage V operating at 1.00 pu and 0.95 pu, on a grid of SCR = 1.2, X/R = 3 and V_{th} = 1.036 pu.

For a given active power (on the horizontal axis in Figure 4), the gap between the red curve (for V = 1.00 pu) and the purple curve (for V = 0.95 pu) in the vertical direction, is the amount of reactive power change required to move the connection point voltage from 0.95 pu to 1.00 pu or from 1.00 pu to 0.95 pu (depending on increasing or decreasing reactive power). For example, Q is -0.10 pu on the red curve and is -0.14 pu on the purple curve when P is 0.5 pu. This means that when a plant is initially operating at P of 0.5 pu, its Q needs to be -0.10 pu to keep the connection point voltage at 1.00 pu. If for any reason the plant Q changes from -0.10 pu to -0.14 pu, the plant voltage will change to 0.95 pu. That is, a 0.04 pu Q decease will lower the plant voltage by 0.05 pu.

An estimation of $\partial Q/\partial V$ in this example is 0.04/0.05 = 0.8 (puQ/puV). If the plant P generation is higher, the gap between red and purple curves becomes narrower, meaning a smaller amount of Q change will result in the same amount of voltage change at the plant connection point, that is, $\partial Q/\partial V$ becomes smaller. At the point where the red curve crosses the purple curve on the right side in the figure, where P is around 1.1 pu, $\partial Q/\partial V$ is close to zero. If P is increased after that point, the plant voltage will be statically unstable, as increasing Q will lower rather than raise the voltage. Note that a voltage step of 0.05 pu is plotted in Figure 4 for ease of reading, for an accurate estimation of $\partial Q/\partial V$, the step should be smaller, or Equation (10) should be directly applied.

A similar feature is also observed on the left side of Figure 4 when the plant is absorbing active power. As the plant absorbs more active power, the gap between the red and purple curves becomes smaller, or $\partial Q/\partial V$ decreases. The plant voltage will become statically unstable when P is around -0.8 pu where $\partial Q/\partial V$ is near zero or negative.

Figure 4 Comparison of static stable parts of PQ loci for connection point voltage V = 1.00 pu vs V = 0.95 pu on a grid of SCR = 1.2, X/R = 3 and V_{th} = 1.036 pu



The SSIAG clearly excludes tests which fall outside of the stable operating region shown in Figure 3, as defined by the acceptance criteria described in sections 7.4.4 (h)[13] and (i)[14]. At the same time, the SSIAG requires the BESS plant (independent of grid-following or grid-forming technology) to be assessed at full rated charging in section 7.4.3 (d)[15]. These two requirements are conflicting, thereby making it impossible for the plant to satisfy both at the same time in low SCR conditions (for example, SCR of 1.2) especially when the X/R ratio is low.

For a specific active power absorption case, Figure 3 presents the power transfer limits. To provide a generic assessment that considers various grid SCR and X/R ratio conditions the static analysis is provided in Section 2.

[13] "The 4.6.6. Connection must not trip unless the operating conditions are outside of *power system* stability limits".

[14] "The 4.6.6. Connection must not continue indefinitely in FRT mode unless the operating conditions are outside of *power system* stability limits".

[15] "…for 4.6.6 Connections comprised of BESS, regardless of whether they are grid-forming or grid-following, all assessments must be conducted at full rated charging and discharging levels up to the maximum registered (or proposed) capacity, including at STATCOM operation (i.e. at zero active power output)".

2 Static analysis

Based on the static stability theory, this section presents case studies exploring the limits of power transfer capability under low SCR and active power absorption conditions. The two static case studies presented below consider unlimited and limited plant reactive power capability and do not distinguish between any particular technology. In the applied case methodology, the connection point voltage of the plant is fixed at levels within the normal operating range, hence the representation of the static stability results differs from the classical QV and PV curve methods, instead using the ∂P/∂θ and ∂Q/∂V representation introduced in Section 1.1.

2.1 Unlimited plant reactive power to keep plant voltage at 1.0 pu

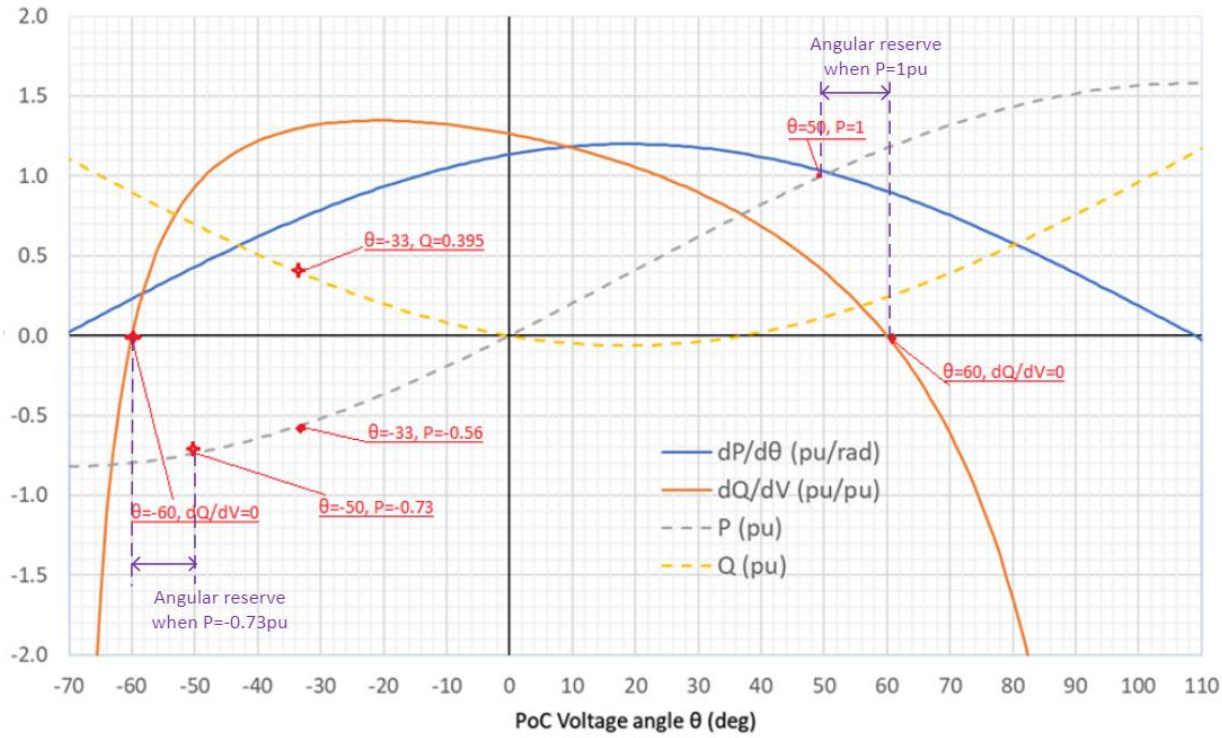
This case is used to demonstrate the transfer capability of a theoretical plant with unlimited reactive power capability. The system is assumed to be a two-bus system, where positive P means the plant is generating:

- The base capacity for SCR and per unit calculation is P_{Rated} (MW), which is the plant rated capacity at the point of connection.
- The grid SCR is 1.2 and the X/R ratio is 3.
- The voltage of Bus A and Bus B are both at 1.0 pu.

Figure 5 presents ∂P/∂θ, ∂Q/∂V, P and Q against Bus A voltage angle θ (relative to infinite bus) of the case with conditions detailed above. The key observations to highlight from Figure 5 are:

1. Voltage stability has a stricter requirement than angle stability.
   - θ range is -59° to 59° for ∂Q/∂V > 0, while it is -70° to 108° for ∂P/∂θ > 0
   - P range is -0.79 pu to 1.16 pu for ∂Q/∂V > 0, while it is -0.82 pu to 1.58 pu for ∂P/∂θ > 0
2. Loads (negative P) have a smaller active power stability limit (in absolute value) than generators (positive P), in two ways
   - P stability limit is -0.79 pu for loading, comparing to the 1.16 pu limit for generating.
   - ∂Q/∂V decreases faster in loading than in generating when P approaches the limits.
3. When the plant is generating 1.0 pu active power, the angular reserve is approximately 10°.
4. If a 10° angular reserve is applied to the plant when it is absorbing active power, the plant cannot absorb more than 0.73 pu active power (i.e., P = -0.73 pu is the limit).
   - Note that the plant is required to send out 0.69 pu reactive power to support the plant staying at 1.00 pu voltage when P = -0.73 pu.
5. If the plant reactive power is limited to 0.395 pu, to maintain 1.0 pu voltage at the plant, the maximum active power that the plant can absorb is 0.56 pu (that is, the operating point left limit in Figure 5 is at θ = - 33° where P = -0.56 pu).

Figure 5 Static stability check on a 2-bus system (SCR = 1.2, X/R = 3, Vth = 1.0 pu, and V = 1.0 pu)



2.2 Limited plant reactive power at ±0.395 pu

The following analysis takes into consideration the limits for the Automatic Access Standard reactive power requirement[16] and the operational voltages in the network. If the following assumption is changed from:

- Bus A voltage is 1.00 pu

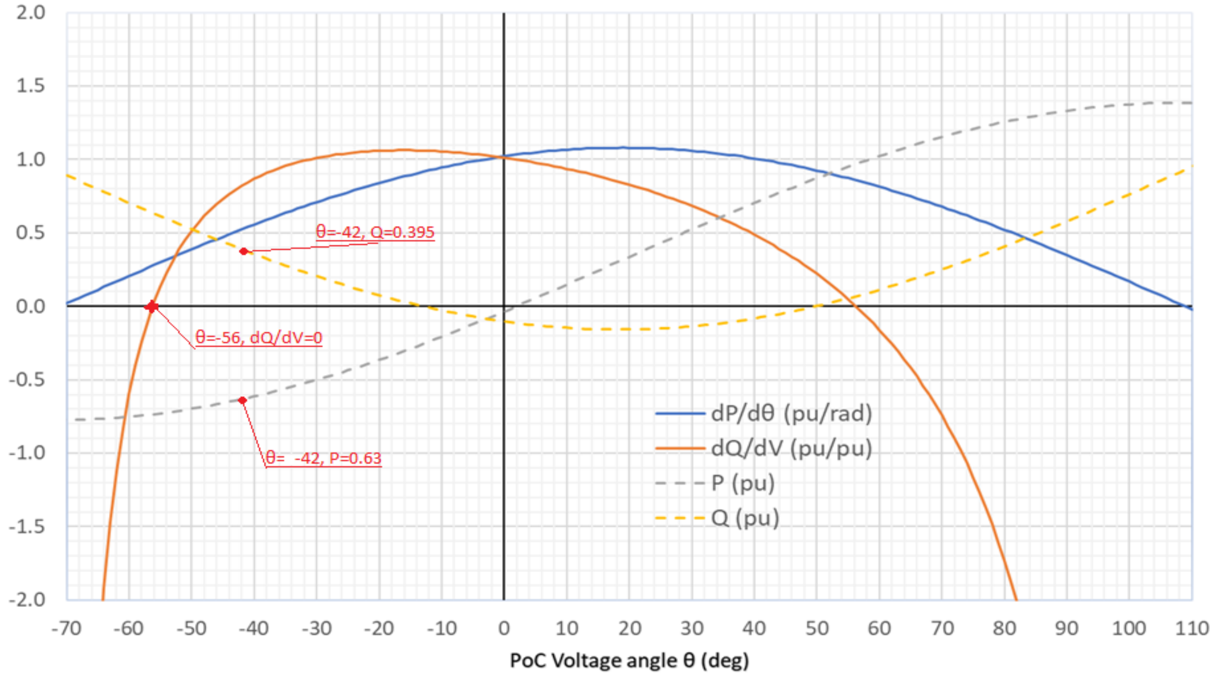
TO

- Bus A voltage is flexible, but must be no less than 0.90 pu, and the plant reactive power must be within ±0.395 pu

then the maximum active power that the plant can absorb is 0.63 pu (that is, active power cannot be more negative than -0.63 pu). This is at the operating point where θ is equal to -42°, as shown in Figure 6.

[16] NER S5.2.5.1

Figure 6 Static stability check on a 2-bus system (SCR = 1.2, X/R = 3, Vth = 1.0 pu, and V = 0.9 pu)



2.3 Proposed criteria in determining static stability limit for plant absorbing active power

Based on the investigation performed, the proposed criteria for determining the active power static stability limit for a plant absorbing active power are:

1. The infinite bus voltage operates as close as possible to 1.00 pu and must not exceed 1.05 pu.
2. For a two-bus grid, the voltage angular reserve is no less than 10° for both $\partial P/\partial\theta > 0$ and $\partial Q/\partial V > 0$[17].
3. Plant reactive power is within ±0.395 pu[18] in steady state.
4. Plant steady state post-disturbance voltage must be 0.90 pu or higher, and as close to 1.00 pu as possible.

In addition to the static stability limit, the connecting plant is also subject to a dynamic stability limit, thermal limit, and other control limits.

[17] 10° angular reserve is considered typical based on SCR of 1.2 and X/R of 3, but can be reduced until 0° provided the stability is maintained.

[18] Unless the reactive power range is otherwise agreed with the connecting NSP.

2.4 Sensitivity analysis for different SCR and X/R ratios

2.4.1 Plant active power absorption limit on a grid with SCR = 1.2

By applying the criteria proposed in Section 2.3, the active power absorption limit of a plant in a two-bus grid is presented by the blue curve in Figure 7. As a comparison, the orange curve in Figure 7 shows the active power limit when the plant reactive power is unlimited and hence the plant voltage can be kept at 1.00 pu.

Figure 7 Plant active power absorption limit on SCR 1.2 grid of different X/R ratios

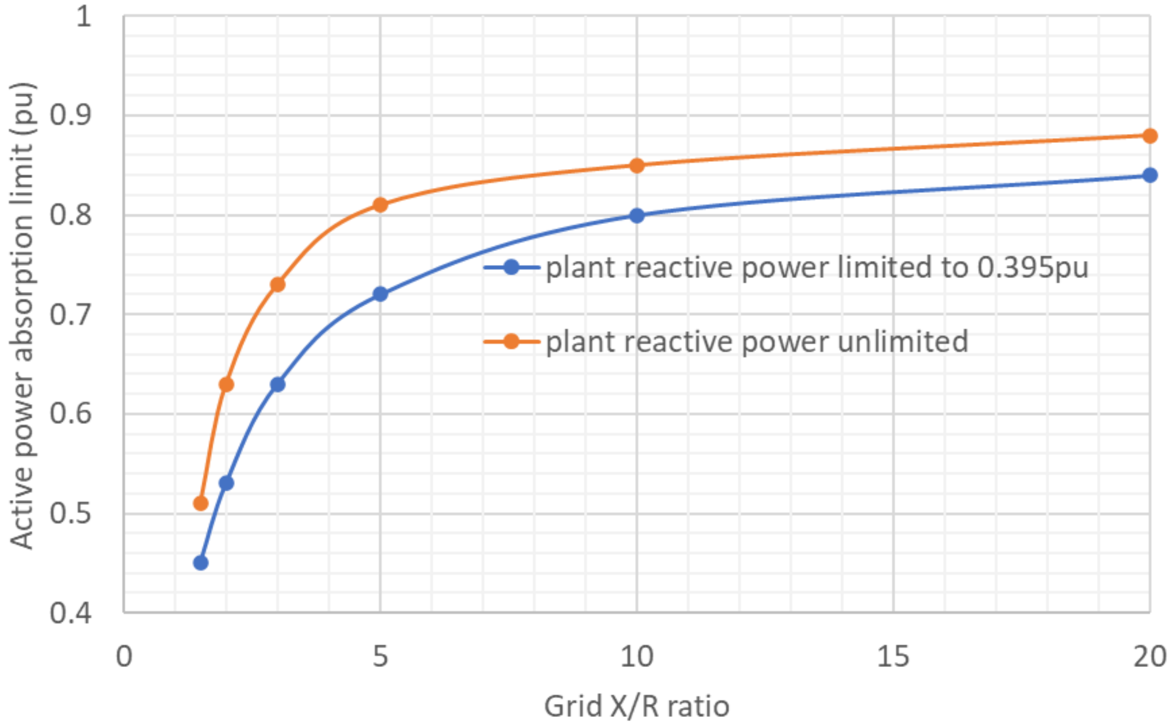


Figure 7 shows:

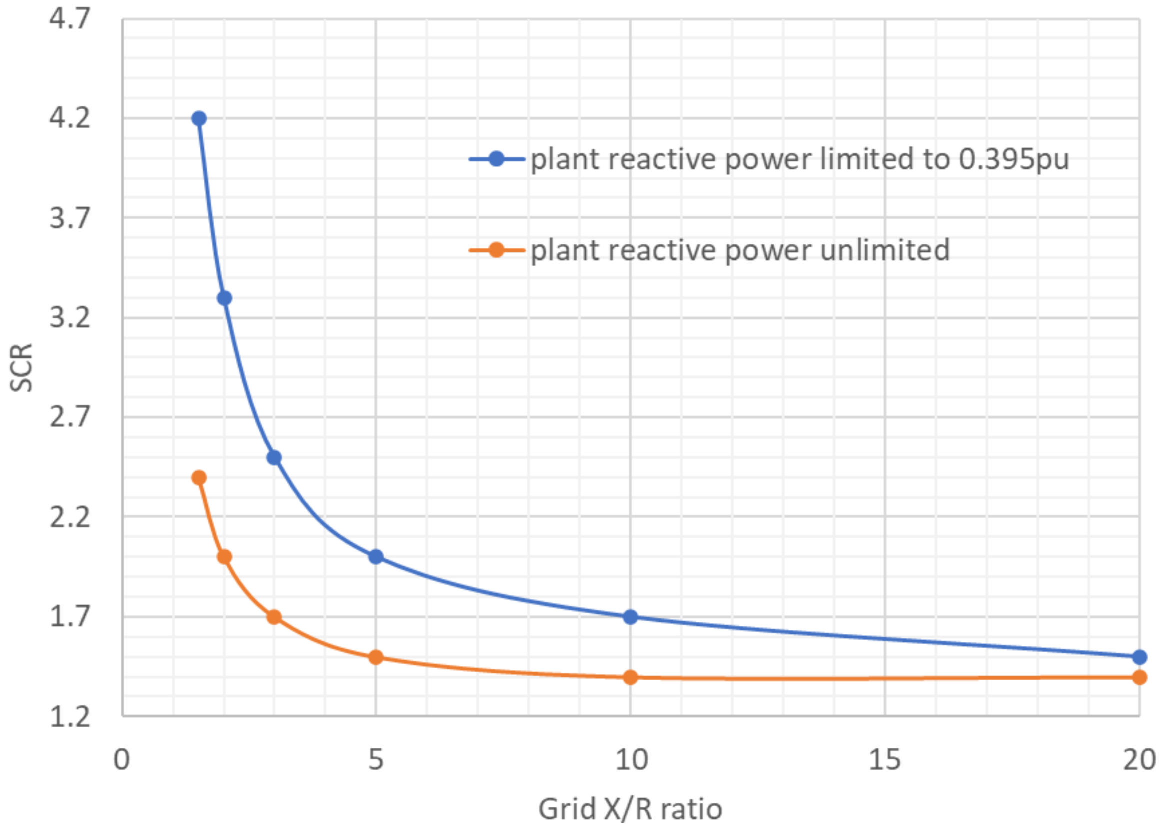
- The active power absorption limit is sensitive to the X/R ratio of the grid
- A lower X/R ratio results in a reduced active power absorption limit.

The lower X/R ratio results in a lower active power absorption limit because, for a given SCR, the active power losses increase as the X/R ratio decreases. Hence, for the same amount of active power sent out from the infinite bus, the amount of active power measured at the plant is lower when the X/R ratio is lower.

2.4.2 Minimum SCR for plant absorbing 1.0 pu active power

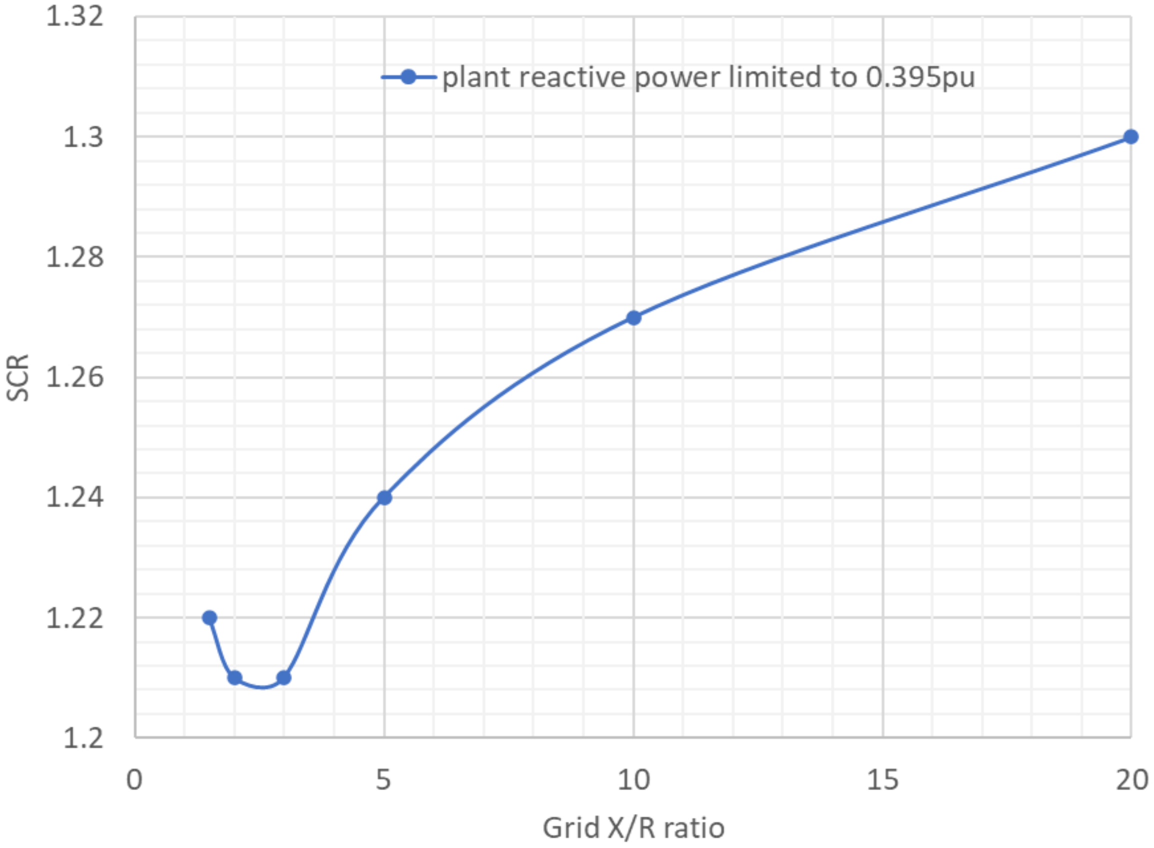
To meet the criteria specified in Section 2.3, when the plant active power absorption is 1.00 pu, the minimum SCR of the grid for X/R ratios between 1.5 and 20 is represented by the blue curve in Figure 8. It can be observed that the minimum SCR is sensitive to the X/R ratio. For example, the minimum SCR is 1.7 when the X/R ratio is 10, but the minimum SCR increases to 2.5 for an X/R ratio of 3. The orange curve in Figure 8 shows the minimum SCR when the plant reactive power is unlimited (and hence the plant voltage can be kept at 1.00 pu).

Figure 8 Minimum SCR requirement for a plant absorbing 1.00 pu active power on different grid X/R ratios



For comparison, Figure 9 presents the minimum SCR requirement for a plant in generation mode that satisfies the criteria in Section 2.3. It shows that for generation mode, the minimum SCR is not as sensitive to the X/R ratio and is between 1.2 and 1.3. The turning point shown in Figure 9, approximately at an X/R ratio of 2.5, is due to the changes between the active and reactive power losses. As the grid becomes more resistive, the active power losses increase together with the minimum SCR at low X/R conditions.

Figure 9 Minimum SCR requirement for a plant generating 1.00 pu active power on different grid X/R ratios



2.5 Impact of SCR and X/R ratio on active power absorption transfer limit

As demonstrated in Sections 2.4.1 and 2.4.2, the plant active power absorption limit that meets the criteria specified in Section 2.3 is sensitive to both the grid SCR and X/R ratio. Table 1 summarises the calculation result of the active power absorption limits for different SCR and X/R ratios. For SCR or X/R ratios that are not shown in Table 1, a two-dimensional linear interpolation lookup method can be used to find the active power absorption limit. As shown in Table 1, by reducing the plant's active power absorption, the two-bus system is statically stable and the power transfer limits are not violated.

Table 1 Two-dimensional linear interpolation table for determining plant active power absorption limit according to grid SCR and X/R ratio

Plant active power absorption limit (pu)							
X/R ratio	**SCR = 1.2**	**SCR = 1.5**	**SCR = 1.7**	**SCR = 2.0**	**SCR = 2.5**	**SCR = 3.3**	**SCR = 4.2**
1.5	0.45	0.53	0.57	0.62	0.72	0.85	1.00
2	0.53	0.61	0.66	0.73	0.84	1.00	1.00
3	0.63	0.73	0.79	0.88	1.00	1.00	1.00
5	0.72	0.85	0.92	1.00	1.00	1.00	1.00
10	0.80	0.95	1.00	1.00	1.00	1.00	1.00
20	0.84	1.00	1.00	1.00	1.00	1.00	1.00

Note: For X/R > 20, apply the value at X/R = 20.

3 Dynamic simulations validation

The static limits presented in Section 2 impose guaranteed limits for stable plant response, assuming ideal plant dynamic voltage control at the connection point. The dynamic stability can be different from the static limit, but the static limit is still the main consideration in the active power absorption.

This section is to provide examples of dynamic stability studies (undertaken in a PSCAD™ SMIB network) for a typical design of an IBR plant considering its internal impedance and voltage control strategy[19]. The plant is assumed to have ±100 megawatts (MW) of capacity at the connection point, with an internal impedance of 18% on 100 megavolt amperes (MVA) base with an option to select grid-following or grid-forming modes.

The PSCAD™ study analyses the dynamic stability of the plant for different control modes, active power levels, grid X/R ratios, and infinite bus voltages.

3.1 Grid-following and grid-forming control mode comparison during active power absorption

From a static stability perspective, the technology or the control mode of the plant has no particular significance. To assess this aspect and to validate the power transfer limits proposed in Table 1, PSCAD™ simulations are performed using both grid-following and grid-forming modes.

Figure 10 shows an example of successful and unsuccessful ride-through when changing the SCR from 10 to 1.2 at fault clearance, with an X/R ratio of 10 for a BESS operating in grid-forming mode. The plant hits its power absorption limits above 0.8 pu active power condition. The simulation results are consistent with Table 1, which defines the plant active power absorption limit at 0.8 pu for an SCR of 1.2 and X/R ratio of 10.

To demonstrate that the static stability issues are independent of the grid-forming and grid-following control modes, the simulation has been repeated for grid-following with the same test conditions. The results are shown in Figure 11. Similarly to the grid-forming mode test case presented in Figure 10, the power transfer limits are violated above 0.8 pu active power absorption.

[19] Note that the studies are undertaken with selected grid-forming (GFM) and grid-following (GFL) models to validate the theory and demonstrate consistency between static analysis and dynamic simulation. The response (e.g. damping and shape of curves) may vary if studied using other models and/or plant configuration.

Figure 10 Successful and unsuccessful ride-through examples on X/R = 10 grid: changing SCR from 10 to 1.2 on fault clearance (GFM)

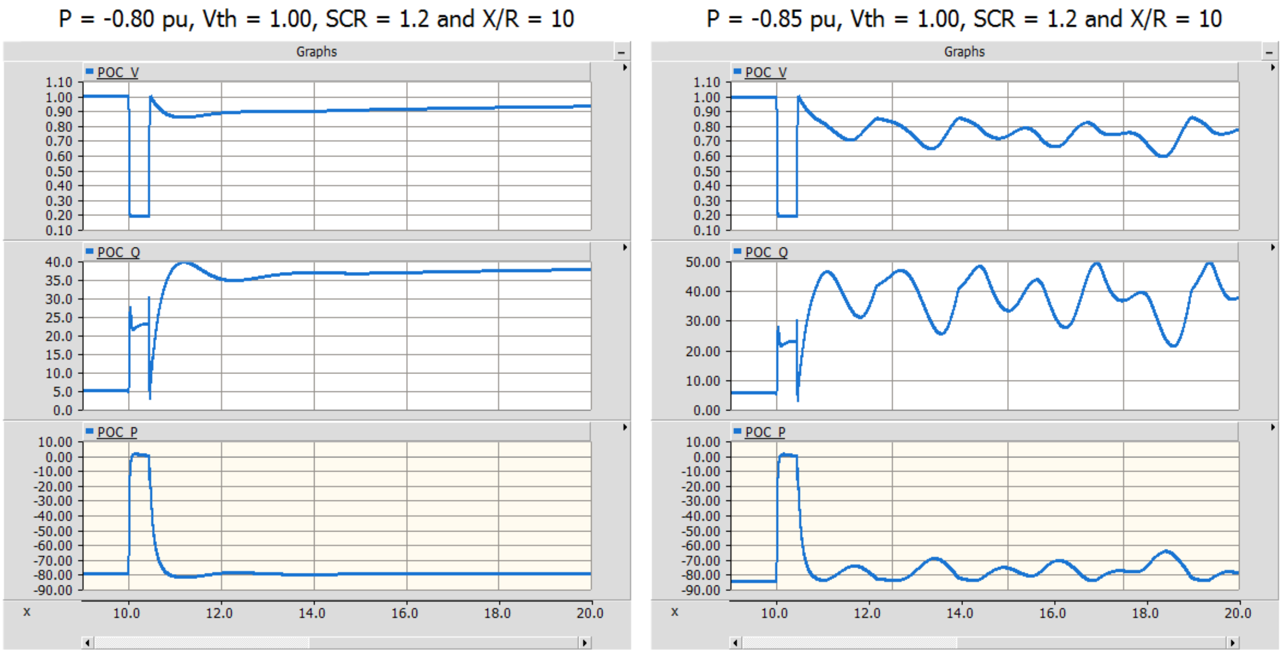
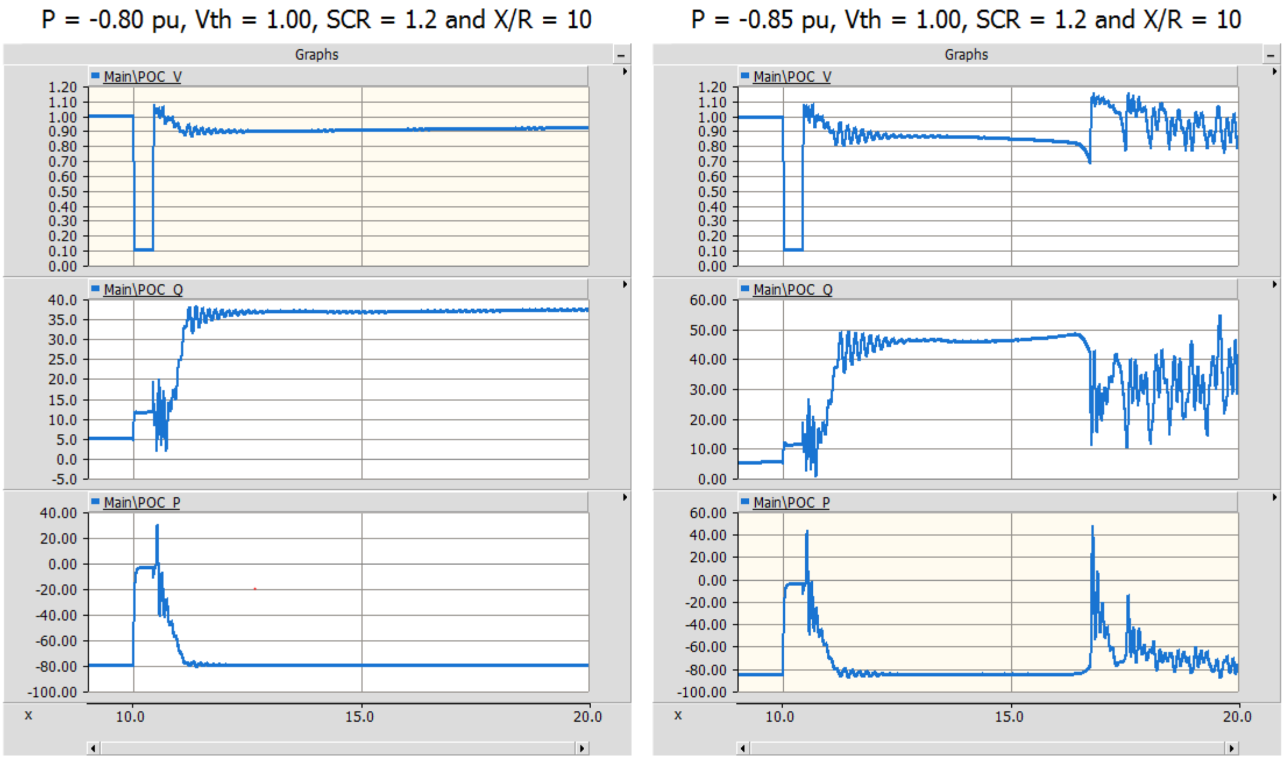


Figure 11 Successful and unsuccessful ride-through examples on X/R=10 grid: changing SCR from 10 to 1.2 on fault clearance (GFL)



While the static stability limits apply uniformly to the different control modes, there are differences in the BESS's dynamic stability for grid-following and grid-forming technology. Comparison of the dynamic stability of grid-forming and grid-following technologies is beyond the intent of this technical note.

3.2 Sensitivity on active power absorption level

To validate the static stability limits summarised in Table 1, additional X/R ratio conditions have been analysed.

Figures 12 and 13 provide examples of successful and unsuccessful ride-through events using grid-following control mode for an SCR of 1.2 and X/R ratio of 3. Reducing the X/R ratio from 10 to 3 creates a more onerous condition for the plant to ride through. According to Table 1, the plant active power absorption limit is 0.63 pu, when operating at an X/R ratio of 3 and SCR of 1.2.

Figure 13 shows that unstable behaviour occurs at 0.7 pu charging active power. Although the system remains stable in the case with charging active power of 0.65 pu, the plant is operating outside of its normal operating conditions at the connection point, with voltage less than 0.90 pu after the fault event. This does not meet the post-fault voltage criteria defined in Section 2.3, even when the plant total capacitive output of 39.5 MVAr is released. Consequently, the simulation verifies the 0.63 pu static stability limit indicated in Table 1.

Figure 12 Successful ride-through examples on X/R=3 grid: changing SCR from 10 to 1.2 on fault clearance (GFL)

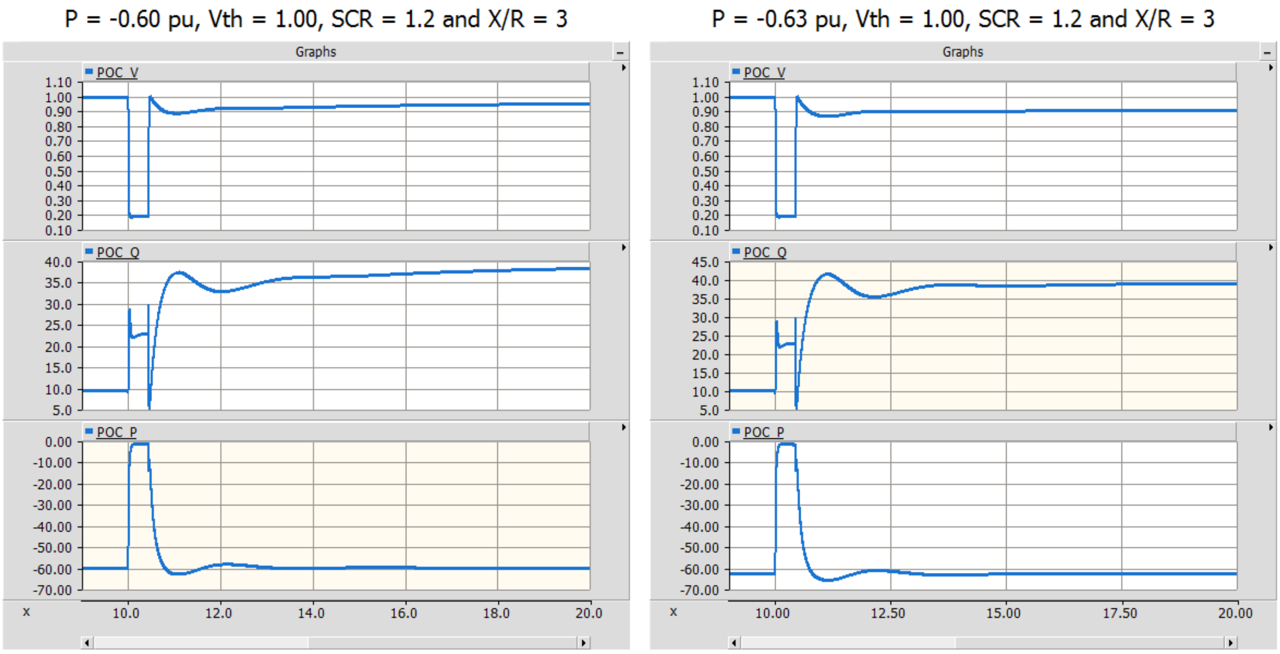
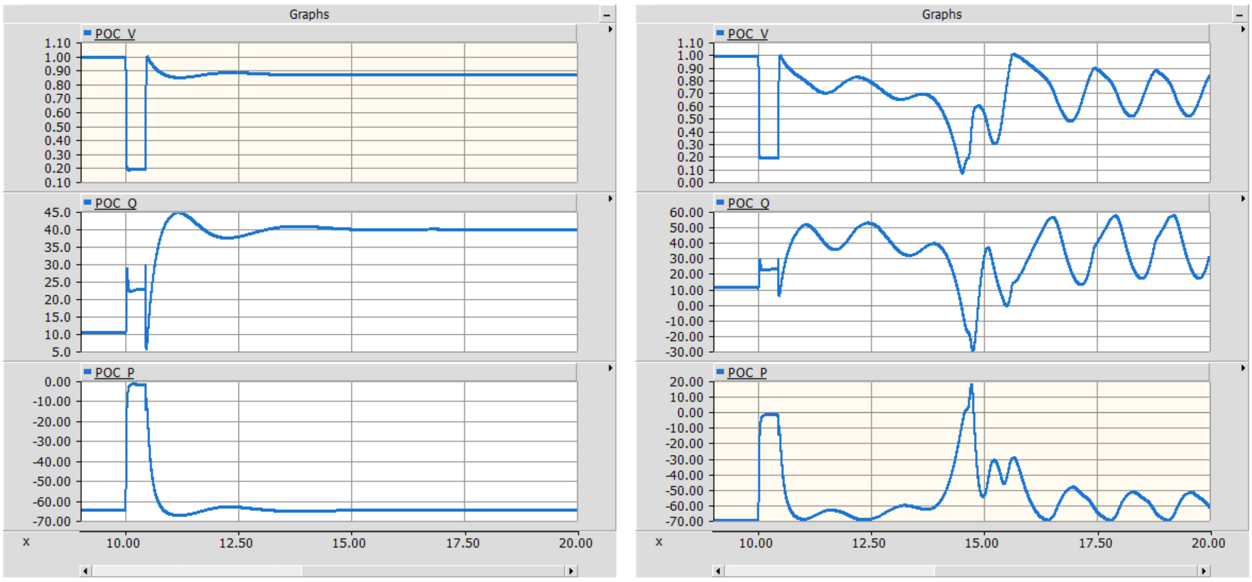


Figure 13 Unsuccessful ride-through examples on X/R=3 grid: changing SCR from 10 to 1.2 on fault clearance (GFL)

P = -0.65 pu, Vth = 1.00, SCR = 1.2 and X/R = 3

P = -0.70 pu, Vth = 1.00, SCR = 1.2 and X/R = 3



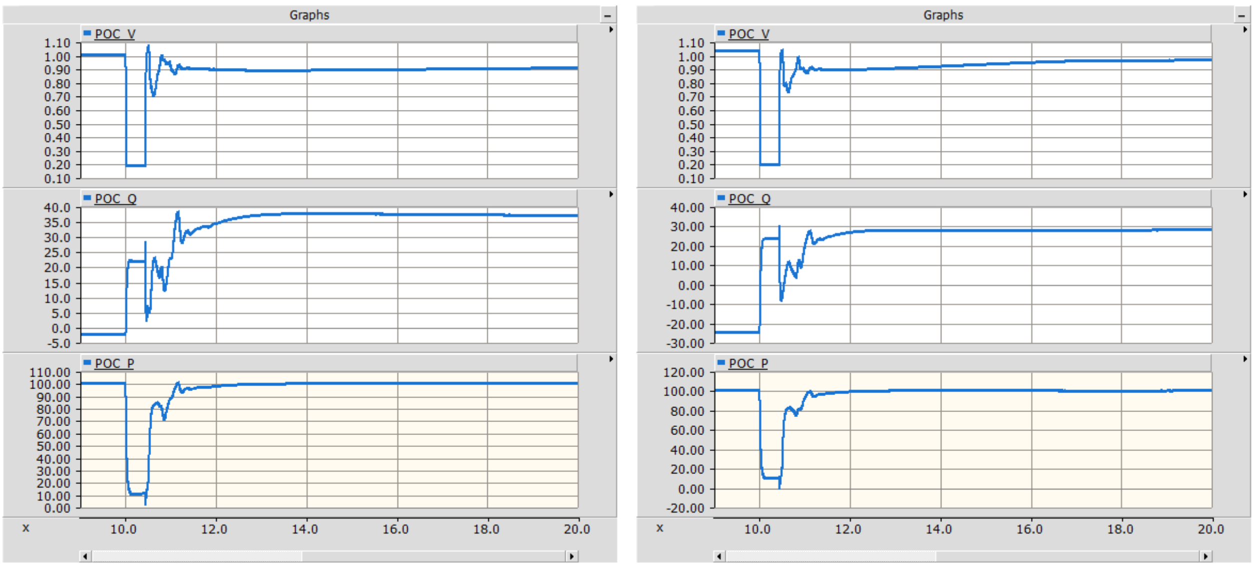
3.3 Sensitivity on infinity bus voltage

Setting the infinite bus voltage has a direct impact on the static stability. In general, higher voltages extend the transfer capability. To demonstrate this, different infinity bus voltages have been studied. Figure 14 presents a successful ride-through event with the inverters operating in grid-following mode. This example demonstrates the influence of the infinity bus voltage (Vth) in the initial and post-fault conditions. The initial voltage and reactive power measured at the connection point will be determined by the selected voltage source setpoint and the plant's overall voltage control strategy. The selection of a 1.05 pu infinity bus voltage instead of a 1.00 pu creates a more favourable condition to ride through the fault, with increased reactive power support provided by the plant.

Figure 14 Successful ride-through examples V_{th} 1.00 pu vs 1.05 pu: (X/R=10, SCR changed from 10 to 1.2 on fault clearance, GFL)

P = 1.00 pu, Vth = 1.00, SCR = 1.2 and X/R = 10

P = 1.00 pu, Vth = 1.05, SCR = 1.2 and X/R = 10



4 Recommendations

This technical note examines the fundamentals of the theory which impacts the limits of power transfer capability in the Withstand SCR tests reflected in the SSIAG. Static analyses alongside dynamic simulations are used to illustrate the limitations of the current SSIAG methodology. As it stands, the guideline requires connecting plant that absorb active power from the network (IBL, hybrid plants and BESS) to undertake tests which result in a breach of power transfer limits. This represents a gap in the current methodology that is impacting some projects in the connections process and has resulted in inconsistent approaches being adopted to overcome the issue.

AEMO proposes clarifications and adjustments to the Withstand SCR test methodology for both generation and load (active power absorption) modes of operation based on the results presented in the previous sections. The proposed clarifications and adjustments in methodology address the limitations inherent in the current methodology when applied to hybrid plants, BESS in charging mode, and variable speed pumped hydro plant in pumping mode. In the case of IBL, AEMO considers that the issue requires further investigation and should be addressed in a separate technical note. In the meantime, AEMO proposes to assess IBL in a similar way as bi-directional plant operating in active power absorption mode. AEMO will review and consider adjustments to the assessment method on a case by case basis until a revised method is developed.

4.1 Steady state voltage and reactive power of All withstand SCR tests

The setting of the infinite bus source voltage is not specified in Tables 2, 3, and 4 in Appendix B of the SSIAG. The assessment result is highly sensitive to this setting due to the plant's available reactive power to support the grid after the fault clearance. This is demonstrated by the simulation results provided in Section 3.3.

Due to the sensitivity of the minimum SCR to changes in the X/R ratio, as presented in Figure 9, and the stability coefficient being fixed at the value of 1.2, the plant violates the static stability limits even in generation mode when the infinite bus voltage is set to 1.00 pu. To avoid this situation and to provide a consistent approach, AEMO proposes to set the infinite bus voltage to 1.05 pu for all tests. The plant steady state voltage at the connection point should be between 0.95 pu and 1.05 pu, and the plant reactive power at the connection point must remain within ±0.395 pu unless otherwise agreed with the connecting NSP.

4.2 Withstand SCR Tests applied to bi-directional plant operating in active power absorption mode

When Withstand SCR is assessed for a variable speed pumped hydro or BESS plant (or a hybrid plant containing BESS) operating in active power absorption mode, the test cases specified in Tables 2, 3, and 4 in the SSIAG must be adjusted. This is required to reflect the static stability limits that apply during active power absorption mode, as summarised in Table 1, when considering the grid SCR and X/R ratio.

The ΔAFL and SSQ calculation equations in the SSIAG[20] are proposed to be changed by substituting P_{rated} in the equations with $P_{capability}$ that is determined as:

$$P_{capability} = maximum\ (\ |P_{min}|, |P_{max}|)$$

where P_{min} and P_{max} are the minimum and maximum steady state active power (in MW) of the plant at the connection point and can be positive or negative.

A positive active power means the active power is flowing from the plant connection point to the external grid.

A plant can have only a single Withstand SCR which is on the $P_{capability}$ base.

P generation mode:

To test plant in active power generation mode, active power at the connection point P_{poc_gen} (in pu on $P_{capability}$ base) is:

$$P_{poc\_gen} = \frac{P_{max}}{P_{capability}}$$

All units must be in either P generation mode or at zero active power at steady state. If P_{poc_gen} is less than 0.05 pu, no tests for plant in P generation mode are required.

P absorption mode:

To test plant in active power absorption mode, active power at the connection point P_{poc_absorb} (in pu on $P_{capability}$ base) is:

$$P_{poc\_absorb} = maximum(-P_{lookup}, \quad \frac{P_{min}}{P_{capability}})$$

where P_{lookup} is the 2-dimensional lookup value from Table 1 according to the Withstand SCR and the site-specific X/R.

If P_{poc_absorb} is greater than -0.05 pu, no tests for plant in P absorption mode are required.

For hybrid plant that can have some units generating and others absorbing active power at the same time, the P absorption mode test must consider two scenarios:

1) Bidirectional units are in P absorption mode and generation-only units are out of service.
2) The active power of bidirectional units are as close to the designed full absorption level as possible, and generation-only units are generating at a level such that the active power at the connection point is equal to P_{poc_absorb}.

4.3 Tests applied to inverter-based load

Power transfer issues like those discussed in the previous sections are also expected for a plant considered as an IBL.

AEMO considers that this issue requires further investigation and should be addressed in a separate technical note. In the meantime, AEMO proposes to assess Withstand SCR of IBL in the similar way as bi-directional plant operating in active power absorption mode. AEMO will review and consider adjustments to the assessment method on a case by case basis until a revised method is developed. Case by case adjustments and further investigations should consider that:

[20] SSIAG 3.4.2 and 6.2.4(c).

- The static stability requirement on minimum SCR for a plant is highly sensitive to the plant reactive power capability, as well as the grid X/R ratio that the plant is connected to.
- IBL have only one direction of active power flow and less flexibility in reducing load levels when compared to BESS.
- Many IBL are thyristor or diode-based converters where the controls are more inferior to a grid-scale IBR.
- IBL may need reactive power compensation for reasons not limited to NER S5.2.5.1 (for example, commutation or harmonics).
- Little experience has been gained in the National Electricity Market (NEM) on the design, connection, and operation of IBL.

4.4 Other changes to withstand SCR tests

Two other issues have been identified in the course of this review, as noted below:

- The minimum set of grid fault tests (Table 2 in Appendix B of the SSIAG) only includes balanced faults (three-phase to ground), with no unbalanced faults.
- The fault duration of 430 milliseconds (ms) for deep voltage dips is unsuitably long.

To address these issues, AEMO proposes:

- Addition of unbalanced fault types (two-phase to ground, two-phase fault without to ground, and single-phase to ground) into the minimum fault set of grid fault tests
- Reducing the fault duration for deep voltage dips according to the nominal voltage of connection point, consistent with the fault clearance times specified in Table S5.1a.2 of the NER

5 Withstand SCR tests

The section sets out the proposed updated test cases (Appendix B of the SSIAG), to address the issues identified in this technical note:

- No specification of infinite bus voltage of the SMIB grid.
- Unsuitable active power absorption level.
- Lack of unbalanced fault test cases.
- Unsuitable long fault duration for deep voltage dips.

It should be noted that this proposal reflects AEMO's current thinking for further consultation and is not an amendment to the SSIAG.

Table 2 Minimum set of grid fault event tests for demonstration of stability (as replacement of Table 2 in Appendix B of SSIAG)

Test	Fault duration [ms]	Fault type	Fault impedance [pu]	Study case settings		
				Common for both P generation and P absorption	Specific for active power generation	Specific for active power absorption
1	80 if Vn is 500kV, 100 if Vn is 330kV or 275kV, 120 if Vn is 220kV or lower	3PHG	Zf = 0.01 x Zs	**Infinite bus voltage:** 1.05 pu. **Grid X/R:** Site-specific X/R at minimum SCR (if it is unknown, use both 3 and 10). **Pre-event and during event grid SCR:** Withstand SCR. **Pre-event reactive power at connection point:** Flexible but is limited by plant reactive power capability at normal temperature and is within plant reactive power limits agreed in GPS. The limits are default to ±0.395 pu if they are unavailable. **Post-event grid SCR:** Withstand SCR. **Post-event voltage, active power and reactive power:** Expected to settle at pre-event values. **V/Q and F/P control modes and setpoints:** Settings in post-event are kept the same as those in pre-event.	**Pre-event voltage at connection point:** 1.05 pu if it is achievable within Q capability and Q limits, otherwise as close to 1.05 pu as possible. **Pre-event active power at connection point:** Equal to $P_{max}/P_{capability}$ in pu. No active power generation test is needed if it is less than 0.05 pu.	**Pre-event voltage at connection point:** As close to 1.00 pu as possible and must be between 0.95 pu and 1.05 pu. Refer to Table 5 and Table 6 for indicative voltage and reactive power. Note Table 5 and Table 6 are to help setting initial case and are not compulsory. **Pre-event active power at connection point:** Equal to maximum ($-P_{lookup}$, $P_{min}/P_{capability}$) in pu, where P_{lookup} is the 2-dimensional lookup value from Table 1 according to the Withstand SCR and the site-specific X/R. No active power absorption test is needed if it is greater than -0.05 pu.
2	80 if Vn is 500kV, 100 if Vn is 330kV or 275kV, 120 if Vn is 220kV or lower	3PHG	Zf = 0.11 x Zs			
3	100 if Vn is 500kV, 120 if Vn is 330kV or 275kV, 220 if Vn is 220kV or lower	3PHG	Zf = 0.25 x Zs			
4	100 if Vn is 500kV, 120 if Vn is 330kV or 275kV, 220 if Vn is 220kV or lower	3PHG	Zf = 0.42 x Zs			
5	430	3PHG	Zf = 0.66 x Zs			
6	430	3PHG	Zf = 1.00 x Zs			
7	430	3PHG	Zf = 1.50 x Zs			
8	430	3PHG	Zf = 2.30 x Zs			
9	430	3PHG	Zf = 4.00 x Zs			
10	430	3PHG	Zf = 9.00 x Zs			
11	100 if Vn is 500kV, 120 if Vn is 330kV or 275kV, 220 if Vn is 220kV or lower	2PHG	Zf = 0.01 x Zs			
12	100 if Vn is 500kV, 120 if Vn is 330kV or 275kV, 220 if Vn is 220kV or lower	2PHG	Zf = 0.18 x Zs			
13	430	2PHG	Zf = 0.43 x Zs			

Test	Fault duration [ms]	Fault type	Fault impedance [pu]	Study case settings		
				Common for both P generation and P absorption	Specific for active power generation	Specific for active power absorption
14	430	2PHG	Zf = 0.82 x Zs			
15	430	2PHG	Zf = 1.50 x Zs			
16	430	2PHG	Zf = 3.00 x Zs			
17	430	2PHG	Zf = 9.00 x Zs			
18	430	2PH	Zf = 0.01 x Zs			
19	430	2PH	Zf = 0.25 x Zs			
20	430	2PH	Zf = 0.50 x Zs			
21	430	2PH	Zf = 1.00 x Zs			
22	430	2PH	Zf = 2.00 x Zs			
23	430	1PHG	Zf = 0.01 x Zs			
24	430	1PHG	Zf = 0.43 x Zs			
25	430	1PHG	Zf = 1.50 x Zs			
Test 26 to 50	The case settings of Test 26 to 50 are same as those of test 1 to 25 respectively except that: a) **Pre-event grid SCR** is 10. b) **Post-event voltage and reactive power at connection point** are determined by plant control.					

Notes:
Vn is the nominal voltage at connection point
Zs is calculated from the pre-event grid SCR and grid X/R
3PHG = 3-phase to ground
2PHG = 2-phase to ground
2PH = Phase to phase (or Line to line) fault, without fault to ground
1PHG = single phase to ground.

Table 3 Minimum set of tests for impulse and voltage step tests (as replacement of Table 3 in Appendix B of SSIAG)

<table>
<tr><th rowspan="2">Test</th><th rowspan="2">Event</th><th colspan="3">Study case settings</th></tr>
<tr><th>Common for both P generation and P absorption</th><th>Specific for active power generation</th><th>Specific for active power absorption</th></tr>
<tr><td>1</td><td>Infinite bus voltage is stepped from 1.05pu at time = 10s to 1.00 pu and is stepped back to 1.05 pu at time = 15s</td><td rowspan="3">Infinite bus voltage: 1.05 pu.

Grid X/R: Site-specific X/R at minimum SCR (if it is unknown, use both 3 and 10).

Grid SCR: Withstand SCR.

Pre-event reactive power at connection point:
Flexible but is limited by plant reactive power capability at normal temperature and is within plant reactive power limits agreed in GPS. The limits are default to ±0.395 pu if they are unavailable.

V/Q and F/P control modes and setpoints: Settings in post-event are kept the same as those in pre-event.</td><td rowspan="3">Pre-event voltage at connection point:
1.05 pu if it is achievable within Q capability and Q limits, otherwise as close to 1.05 pu as possible.

Pre-event active power at connection point:
Equal to $P_{max}/P_{capability}$ in pu. No active power generation test is needed if it is less than 0.05pu.</td><td rowspan="3">Pre-event voltage at connection point:
As close to 1.00 pu as possible and must be between 0.95 pu and 1.05 pu.
Refer to Table 5 and Table 6 for indicative voltage and reactive power. Note Table 5 and Table 6 are to help setting initial case and are not compulsory.

Pre-event active power at connection point:
Equal to maximum($-P_{lookup}$, $P_{min}/P_{capability}$) in pu, where P_{lookup} is the 2-dimensional lookup value from Table 1 according to the Withstand SCR and the site-specific X/R. No active power absorption test is needed if it is greater than -0.05 pu.</td></tr>
<tr><td>2</td><td>Infinite bus voltage impulse from 1.05 pu to 1.00 pu is applied at time = 10s for a duration of 40ms</td></tr>
<tr><td>3</td><td>Infinite bus voltage impulse from 1.05 pu to 0.95 pu is applied at time = 10s for a duration of 40ms</td></tr>
</table>

Table 4 Minimum set of tests for impedance change to SCR of 3.0 (or lower) (as replacement of Table 4 in Appendix B of SSIAG)

Test	Event	Study case settings		
		Common for both P generation and P absorption	Specific for active power generation	Specific for active power absorption
1	At time = 10s grid impedance is changed, and kept unchanged for 30s	**Infinite bus voltage:** 1.05 pu. **Grid X/R:** Site-specific X/R at minimum SCR (if it is unknown, use both 3 and 10). **Pre-event grid SCR:** 10. **Post-event grid SCR:** Withstand SCR. **Pre-event and post-event reactive power at connection point:** Flexible but is limited by plant reactive power capability at normal temperature and is within plant reactive power limits agreed in GPS. The limits are default to ±0.395 pu if they are unavailable. **V/Q and F/P control modes and setpoints:** the settings in post-event are kept the same as those in pre-event.	**Pre-event voltage at connection point:** 1.05 pu if it is achievable within Q capability and Q limits, otherwise as close to 1.05 pu as possible. **Pre-event active power at connection point:** Equal to $P_{max}/P_{capability}$ in pu. No active power generation test is needed if it is less than 0.05 pu.	**Pre-event voltage at connection point:** As close to 1.00 pu as possible and must be between 0.95 pu and 1.05 pu. Refer to Table 5 and Table 6 for indicative voltage and reactive power. Note Table 5 and Table 6 are to help setting initial case and are not compulsory. **Pre-event active power at connection point:** Equal to maximum($-P_{lookup}$, $P_{min}/P_{capability}$) in pu, where P_{lookup} is the 2-dimensional lookup value from Table 1 according to the Withstand SCR and the site-specific X/R. No active power absorption test is needed if it is greater than -0.05 pu.

Table 5 V Lookup Table – Indicative POC voltage (pu) for P absorption tests

X/R	SCR = 1.2	SCR = 1.5	SCR = 1.7	SCR = 2.0	SCR = 2.5	SCR = 3.3	SCR = 4.2
1.5	0.9900	0.9710	0.9700	0.9715	0.9645	0.9640	0.9612
2	0.9948	0.9835	0.9785	0.9735	0.9685	0.9652	0.9957
3	1.0000	0.9915	0.9855	0.9780	0.9775	1.0000	1.0000
5	1.0000	1.0000	0.9995	1.0000	1.0000	1.0000	1.0000
10	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Note: For POC indicative voltage < 1.00 pu in the table, it is assumed that POC reactive power is limited at 0.395 pu.

Table 6 Q lookup table: Indicative POC reactive power (pu, capacitive sent out) for P absorption tests

X/R	SCR = 1.2	SCR = 1.5	SCR = 1.7	SCR = 2.0	SCR = 2.5	SCR = 3.3	SCR = 4.2
1.5	0.395	0.395	0.395	0.395	0.395	0.395	0.395
2	0.395	0.395	0.395	0.395	0.395	0.395	0.395
3	0.384	0.395	0.395	0.395	0.395	0.332	0.239
5	0.355	0.389	0.395	0.389	0.290	0.187	0.103
10	0.332	0.365	0.343	0.266	0.179	0.084	0.003
20	0.316	0.347	0.281	0.209	0.125	0.033	-0.046