AEMC

RULE

Australian Energy Market Commission

CONSULTATION PAPER

EFFICIENT REACTIVE CURRENT ACCESS STANDARDS FOR INVERTER-BASED RESOURCES

PROPONENTS

Renewable Energy Revolution Pty Ltd
Goldwind Pty Ltd, Siemens Gamesa, GE International Inc., Vestas

26 MAY 2022

INQUIRIES

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ABOUT THE AEMC

The AEMC reports to the Energy Ministers' Meeting (formerly the Council of Australian Governments Energy Council). We have two functions. We make and amend the national electricity, gas, and energy retail rules and conduct independent reviews for the Energy Ministers' Meeting.

EXECUTIVE SUMMARY

The National Electricity Market (NEM) is going through a massive transition. It is moving from thermal plants to inverter-based renewable generators and batteries, and from large generators to smaller, more dispersed generators. A significant amount of new generation is required — the Australian Energy Market Operator's (AEMO) latest draft Integrated System Plan forecasts that an additional 122 gigawatts (GW) of utility scale variable renewable energy is forecast to be installed in the NEM by 2050. Given the current and forecast scale of new connections, it is imperative that the connection process is as efficient as possible while still assessing connections on all relevant criteria in the interest of maintaining a secure power system.

The Commission is currently considering two rule change requests relating to the access standards that inverter-based resources must comply with to connect to the NEM. One was submitted by Renewable Energy Revolution Pty Ltd (RER) on 2April 2019 and the other by a consortium of wind turbine original equipment manufacturers (OEMs) on 11 March 2021.[1] As both proposals relate to the amount of reactive current that generators should be required to supply, the Commission has consolidated these requests and will consider them together.[2]

Power system equipment and loads are designed around certain operating voltage ranges. Hence, voltage needs to be regulated to ensure proper operation of the power system and the connected loads. In contrast to frequency regulation, which is a system-wide need, the need for voltage regulation is localised. The voltage profile itself should be within acceptable harmonic levels and be held sufficiently far from the point of voltage collapse to minimise the risk of cascading failures. Where active power is the tool used to manage frequency, reactive power via reactive current is used to manage voltage levels.

Generators, loads and bi-directional units must prove that they can comply with a suite of 'performance standards' when they connect to the NEM. This is to ensure that connecting plant behave in a predictable manner that benefits the security and stability of the power system both in steady-state conditions and following disturbances. These standards are agreed between the connecting party and the Network Service Provider (NSP) who is typically advised by AEMO. For most performance standards, the National Electricity Rules (NER or "the Rules") stipulate a minimum standard and an automatic standard. If the connecting plant exceeds the automatic standard then the NSP cannot deny their connection on these grounds, while the minimum standard represents the lowest acceptable level anywhere in the NEM. Typically, generators and NSPs negotiate what the standard may be in a particular instance, and agreement is reached on a level somewhere between the minimum and automatic standard.

1 The consortium is made up of GE International Inc, Goldwind Australia Pty Ltd, Siemens Gamesa Renewable Energy Pty Ltd, Vestas Australia Wind Technology Pty Ltd.

2 The Commission has determined to consolidate its assessment of the two rule change requests under section 93(1)(a) of the NEL.

The wind turbine OEMs have identified several issues with the current minimum access standards that apply to the amount of reactive current capability that inverter-based generators must provide following a fault. They consider that:

- the standards are set at an inappropriate level
- compliance is not defined in a way that is mutually understood by AEMO, TNSPs and connecting proponents
- inconsistencies exist between these and some related standards that make it difficult to comply with all of them.

Similarly, RER considers that the existing reactive current injection standard is inappropriate for low inductance resistance ratio (X/R) areas of the network. They consider that it should be changed to a standard that varies with connection-point X/R, to better reflect the needs of the network.

The AEMC has commenced its assessment of the rule change requests, and this consultation paper is the first stage of our rule making process. This consultation paper seeks to establish an evidence base that will help us determine whether we should make the rule as proposed, make a more preferable rule, or make no change to the NER. We are seeking your feedback on:

- how we propose to assess the request to determine if it will promote the long-term interests of consumers
- the problems raised by the rule change proponents and their materiality
- the proposed solutions including whether there are alternatives that are more likely to contribute to the achievement of the National Electricity Objective (NEO).[3]

We are seeking your views on the problems that current arrangements present for efficient investment in reactive current capability

Both rule change proposals consider that changes should be made to the reactive current fault-response minimum access standards, as the existing standards do not suit the needs of the system, at all points in the network. The wind turbine OEMs consider that the current standards:

- worsen the commercial viability of inverter-based generation which delays timely investment in new capacity and/or raises wholesale generation costs that consumers pay for, or reduces the amount of generation capacity that can be connected in a particular part of the network
- duplicate investments in equipment that aims to maintain stable voltage levels on the network and generator side, risking asset stranding

3 Section 88 of the NEL.

- lead to challenges with coordinating reactive current response when faults occur, noting that it is especially challenging to meet onerous standards for voltage control after reactive power is injected or absorbed.

By comparison, RER considers that the current standard may:

- lead to insufficient voltage support during faults at connection points with low X/R ratios
- degrade inverters' ability to track voltage during and after faults.

We are also seeking your views on the proponents' solutions to address the problems identified and whether there are alternatives that the Commission should consider

The wind turbine OEM rule change proponent has proposed four solutions to address the problems they have identified in their rule change proposal. The proponent states that these solutions:

- resolve the risks to the commercial viability of new generation and investment duplication by lowering the minimum level of reactive current capability that generators have to install at the connection point to zero
- resolve challenges with coordinating a generator's reactive current response, by both shifting the point of compliance assessment from the connection point to the generator unit terminals and by making the standards describing the characteristics of that response (i.e. when a response should commence, and how quickly it should stabilise) less onerous
- resolve other issues that are creating uncertainties for the grid approvals process by clarifying potential conflicts between obligations to provide a reactive power response that helps maintain stable voltage levels and an active power response that helps maintain stable frequencies.

RER has proposed a move away from the current static maximum reactive current fault-response requirement of 100% of the unit's maximum continuous current. Instead, they have recommended a maximum reactive current response that is less than 100% and varies based on the X/R ratio of the connection point. They suggest this is because at low X/R ratios, active power can help support voltage, like reactive power, with this effect decreasing as the X/R increases. Mandating a maximum reactive current response of less than the maximum continuous current will allow a greater amount of active current response, further supporting voltage.

To establish whether the solutions proposed by the wind turbine OEMs' rule change proposal or that submitted by RER Pty Ltd meet the NEO, the Commission needs to establish a view on the following issues:

- What implications might lowering the minimum access standard that applies to the reactive current capability that inverter-based resources have to install have on system security and would lowering this standard lead to networks bearing some of the costs of providing voltage stability services?

- What implications might the current standards be having on the cost and complexity of ensuring stable voltage levels at the point at which inverter-based resources connect to the network?
- Are the static maximum reactive current fault response requirements appropriate at all points in the network, or should they be varied based on locational network characteristics?
- What are the costs and benefits of changing the point of compliance assessment from the connection point to the terminals of each generating unit and whether other changes to voltage stabilisation and response commencement criteria will materially improve the efficiency of the connection assessment process?
- What other conflicts are current reactive current response standards creating for the amount of active power generators have to inject after a fault clears, and are these standards presenting barriers to the timely and efficient assessment of connection applications?

In assessing the possible solutions to resolve the issues identified by the proponents, the Commission may also consider the ability of large-scale inverter-based loads like electrolysers to provide reactive current following short duration faults that lead to voltage disturbances and whether this could assist in resolving voltage issues. This is likely to be an important emerging issue, as AEMO's draft ISP has forecast a significant volume of new electrolytic load to be installed as the prospects for the electricity system to contribute to the decarbonisation of the hard-to-abate industrial sectors of the economy gain momentum.[4] We are also interested in stakeholder views on whether this is a valid option to deal with the issues identified by the proponents or whether there are other solutions that the AEMC should consider.

In assessing this request, we propose to consider three assessment criteria

In considering the NEO and the issues raised in the rule change request, the Commission proposes to assess whether a change to the NER to modify the reactive current response requirements following a contingency event, supports or promotes:

- **Security and reliability:** the Commission will assess whether the standard is set at the right level by balancing benefits for system security, and timely investment in new generation against the costs of installing reactive power capacity to meet that standard.
- **Cost allocation:** the Commission will assess whether the current standard balances the cost of achieving system security against the broader benefits for system security and reliability and whether the standard is set in a way that minimises the complexity of the grid approvals and compliance assessment process for connecting parties, and AEMO.
- **Efficient risk allocation to preserve competition where appropriate**: the Commission will assess how a revised standard can minimise duplication of assets on the network and generator sides of the supply chain and allocate costs of delivering reactive

4 AEMO Draft 2022 Integrated System Plan December 2021, pp. 25-8.

current support between networks and generators by assessing how scale efficiencies in reactive power equipment can achieve the NEO at least cost.

- **Transparency and simplicity**: the Commission will look to this criterion to ensure connecting parties have clarity on their obligations — including what capabilities they need to demonstrate before connection approval is granted to ensure efficient assessment and compliance monitoring.

Written submissions are due on 23 June but the Commission will continue to engage with industry initiatives to reform access standards to ensure efficient use of stakeholder resources

In early 2021, AEMO and the Clean Energy Council established the Connections Reform Initiative to address concerns with delays and increasing complexity in connections to the NEM. Ultimately 11 reforms were recommended. One of these was to lower the minimum access standard that specifies the amount of reactive current capability that inverter-based generators are required to install.

This is relevant to this rule change, as the CRI's work aims to influence the establishment of an access standard that better reflects network performance and system needs at the connection point and in doing so provide AEMO, NSPs, project proponents and OEMs more flexibility to negotiate performance standards while minimising process uncertainty and other risks to stable and secure system operation. The AEMC will consider the work that the CRI has undertaken in our assessment of the rule change requests, and will work closely with the CRI as this rule change progresses.

Written submissions responding to this consultation paper must be lodged with Commission by 23 June 2022 via the Commission's website, www.aemc.gov.au.[5] There may be other opportunities for you to engage with us, such as one-on-one discussions or industry briefing sessions if they would help you clarify concerns and respond to the questions in this paper.

Please contact the project leader with questions or feedback at any stage. The project leader for this rule change is Ashok Kaniyal who can be contacted on 0403 691 321 and ashok.kaniyal@aemc.gov.au.

The next step in our rule making process is preparing the draft determination. We expect to publish this on 3 November 2022. This timeline extends our normal consultation process by approximately two months relative to our standard timeline. We have made this decision to allow time to establish a stronger evidence base to make a decision, undertake externally commissioned qualitative and quantitative studies and consult on those studies (e.g. through technical working groups) before making our draft determination.

5 The submission must be on letterhead (if submitted on behalf of an organisation), signed and dated. Where practicable, submissions should be prepared in accordance with the Commission's guidelines for making written submissions on rule change requests. The Commission publishes all submissions on its website, subject to a claim of confidentiality.

FULL LIST OF CONSULTATION QUESTIONS

QUESTION 1: ASSESSMENT FRAMEWORK

Do stakeholders agree with the proposed assessment framework? Alternatively, are there additional principles that the Commission should take into account or are there principles included here that are not relevant?

QUESTION 2: HAS THE COMMISSION CHARACTERISED THE PROBLEMS CREATED BY EXISTING ARRANGEMENTS FOR SECURITY AND RELIABILITY CORRECTLY?

- Are the current standards efficient? If current standards are too onerous, what impacts are the reactive current capability standards having on the viability of new resources connecting to the system? Can these impacts be quantified?
- Can the impacts of the reactive current standards on system security be quantified? If not, under what specific circumstances do the coordination challenges presented by too much reactive current capacity create system security risks?
- What implications might emerging technologies have for existing reactive current capability standards? What are the cost and regulatory complexity implications of emerging technologies providing reactive current to support voltage stability?

QUESTION 3: HAS THE COMMISSION CORRECTLY CHARACTERISED THE PROBLEMS THAT CURRENT ARRANGEMENTS MAY BE PRESENTING FOR THE EFFICIENT ALLOCATION OF RISKS?

- Is the current allocation of responsibilities between NSPs and generators for providing voltage support services maximising system security benefits across the power system?
- If the current allocation is inefficient, what impacts or costs are current arrangements placing on generators' or network businesses' abilities to ensure a secure system at least cost?
- Can competition drive meaningful innovation that will reduce the cost of delivering voltage support services over time?

QUESTION 4: MORE TRANSPARENT AND SIMPLER GRID APPROVALS

- What problems are the existing minimum access standards on reactive current presenting for more transparent and simple grid approvals?
- Can the cost of these problems be quantified in terms of the typical amount of time it currently takes for grid approvals and how much faster it could be if the Rules were simpler?

QUESTION 5: EVIDENCE TO SUPPORT CHANGING THE POINT OF COMPLIANCE FROM THE CONNECTION POINT TO GENERATOR UNIT TERMINALS

- What factors should guide the Commission's assessment of how to determine the reactive current capability standard that should apply to inverter-based generation?
- What are the implications of limiting the minimum reactive current response capability that inverter-based generators have to provide, to the relationship proposed by RER in Table 1?

QUESTION 6: WHAT SHOULD THE MINIMUM REACTIVE CURRENT CAPABILITY BE?

- If the point of compliance remains at the connection point, at what level should the minimum reactive current capability that generators have to install be set?
- What potential risks to system security are there from lowering the minimum reactive current capability to this level?
- What are the potential benefits for reliability and efficient investment in generation from lowering the reactive current capability?

QUESTION 7: WHAT ARE THE BENEFITS OF ALIGNING REACTIVE CURRENT CAPABILITY TO LOCATIONAL SYSTEM STRENGTH NEEDS?

- To reduce the risk of investment duplication, should the minimum level of reactive current capability take into account the available / forecast level of dynamic voltage support from System Strength Service Providers?
- What are the potential implications for the future development of grid forming inverters from lowering the minimum reactive current capability that inverter-based generators have to provide?

QUESTION 8: EVIDENCE TO SUPPORT CHANGING THE POINT OF COMPLIANCE FROM THE CONNECTION POINT TO THE GENERATOR UNIT TERMINALS

- What are the distinctions between steady-state compliance and dynamic response that the Commission needs to consider in assessing whether to change the point of compliance assessment from the connection point to the generator unit terminals?
- What specific implications does this have for the connections assessment process and does this outweigh the cost of high-speed monitoring that is needed at each unit terminal to assess compliance?

QUESTION 9: WHAT CHALLENGES DOES THE CURRENT VOLTAGE TRIGGER RANGE PRESENT FOR INVERTER-BASED GENERATORS IN MEETING THE EXISTING REACTIVE CURRENT CAPABILITY MINIMUM ACCESS STANDARD?

- What are the implications for generator connection applicants of maintaining the rule that the response be triggered at a range of connection point voltages?
- What other implications might lowering the minimum reactive current capability that generators are required to provide have for the voltage level or range that triggers a generator's reactive current response?

QUESTION 10: WHAT ARE THE KEY ISSUES WITH THE RISE AND SETTLING TIME STANDARDS?

- What stakeholder experiences over the past three years support a Commission decision to revise the current rise and settling time access standards?
- What should the rise and settling time be revised to if the point of compliance assessment is maintained at the connection point instead of the generator unit terminals?
- How should the rise and settling time standards change with the minimum reactive current response capability, if at all?

QUESTION 11: HOW SHOULD THE MINIMUM ACCESS STANDARDS THAT APPLY TO ACTIVE POWER RECOVERY BE CLARIFIED?

- Is there a conflict between the obligations for active power recovery after fault clearance to ensure stable frequency levels and the obligations in S5.2.5.5 for active power to recover to 95% of pre-fault levels after a fault occurs?

- How should this conflict be clarified to ensure clarity on generators' obligations to return to continuous uninterrupted operation in a timely manner?

QUESTION 12: IMPLEMENTATION CONSIDERATIONS THAT THE COMMISSION SHOULD TAKE INTO ACCOUNT

- How quickly should any new access standards come into effect?
- What are the potential unintended consequences of bringing these into effect immediately (e.g. for new connection applications)?
- What are the implications of providing project proponents the option to connect under the existing or the new standard (e.g. for advanced projects that have already been approved or close to securing grid approvals)?

CONTENTS

APPENDICES

TABLES

1 INTRODUCTION

This consultation paper seeks stakeholder feedback on two rule change requests seeking to change the arrangements for the amount of reactive current that is required to be provided by generators in response to disturbances following contingency events under the minimum access standards for generators in Schedule 5.2 of the National Electricity Rules.

We include questions in each chapter to guide feedback, but you are welcome to provide feedback on any additional matters that may assist the Commission in making its decision.

1.1 Key elements of the connection framework

Under the National Electricity Rules (NER) connections framework, connection applicants are able to negotiate with a network service provider (who is advised on some matters by AEMO) on the level of performance they have to demonstrate for the equipment they are seeking to connect to the power system.[6] For each technical requirement, the negotiation occurs within a range provided by:

- the minimum access standard — below which a connection must be denied access if it is unable to meet that technical requirement, and;
- the automatic access standard — above which a connection cannot be denied access on the basis of that technical requirement.[7]

The agreement reached is then recorded in the applicants' generator performance standard, which their plant must comply with on an ongoing basis.[8]

In 2018, the generator technical performance standards (GTPS) were amended by the *Generator technical performance standards* rule[9] that improved and clarified the negotiating process for connections so that they can occur more efficiently, and so that each connection has a level of performance that allows them to efficiently manage frequency and voltage within acceptable limits.[10]

Among several changes made to generator access standards were requirements for generating systems to be able to inject and absorb reactive current during disturbances, so that all connecting generators can assist by supporting voltage levels in a predictable way when there are faults on the power system. In addition to establishing the minimum level of reactive power capability to support the security of the power system and the quality of supply, the NER also specify the characteristics that the generating system's reactive power response must have.

6 AEMC, Generator technical performance standards, rule determination, 27 September 2018, p. iii.
7 AEMC, Generator technical performance standards, rule determination, 27 September 2018, p. iii.
8 AEMC, Generator technical performance standards, rule determination, 27 September 2018, p. viii.
9 National Electricity Amendment (Generator technical performance standards) Rule 2018 No. 10.
10 AEMC, Generator technical performance standards, rule determination, 27 September 2018, p. i.

1.2 Proposals are to lower the minimum reactive current capability that generators have to install for grid approval

On 11 March 2021, a consortium of wind turbine original equipment manufacturers (OEMs) submitted a request to the Australian Energy Market Commission (AEMC or Commission) proposing changes to the minimum access standards that set out how much reactive current capability[11] needs to be installed before network service providers (NSP) can provide generators with connection approval. This rule change request followed a related rule change request submitted on 2 March 2019 by Renewable Energy Revolution Pty Ltd (RER).

The wind turbine OEMs' proposal is broad and has three objectives:

- To revise the minimum reactive current response capability that generators need to meet following a contingency event, to one that better reflects local power system needs[12] and reduces the risk of duplication of investments on the network and generation side;[13]
- To shift the point of compliance assessment from the connection point to the generator unit terminals;[14] , and;
- To resolve regulatory uncertainty created by standards that are difficult to co-optimise into the design of large wind farms and by clarifying definitions of some terms in the NER.[15]

RER's proposal is narrower but also recommends that the Commission focus on making changes to the current minimum reactive current capability access standard that applies to inverter-based generators. They propose to change the minimum and automatic reactive current injection standards following a fault, to reduce the maximum response from 100% of the maximum continuous current to a lower value that is dependent on the connection point reactance to resistance (X/R) ratio. RER note that this revision would account for the contribution that the active current response makes to help support stable voltage levels in certain low X/R network locations.

Further detail on the changes proposed by the rule change requests are set out in chapter 4.

The wind turbine OEMs consider that the relevant NER access standard clauses:

- create barriers to entry for small generators securing connection agreements as the minimum reactive current capability standard is too high
- may lead to the installation of too much reactive current capability that is hard to coordinate at a system level when faults occur

11 Power in AC circuits is comprised of active power and reactive power. Active power allows work at the point of end use (i.e. heat, light motion). Reactive power on the other hand indirectly supports active power by maintaining stable voltages. See Appendix 1 for further information on the differences between active power and reactive power.

12 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, pp. 13-4.

13 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, p. 16.

14 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, pp. 8, 19-20.

15 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, pp. 20-1.

- are challenging to demonstrate compliance with, as in some cases it is not possible for both the reactive current capability requirement to be co-optimised with the minimum response stability and frequency management standards

In comparison, RER considers that the current standard may:

- lead to insufficient voltage support during faults at connection points with low X/R ratios
- degrade inverters' ability to track voltage during and after faults.

Further details on the problems raised by the rule change requests are set out in chapter 3.

We include questions in each chapter to guide feedback, but you are welcome to provide feedback on any additional matters that may assist the Commission in making its decision.

1.2.1 Interactions with the Connections Reform Initiative

In early 2021, AEMO and the Clean Energy Council (CEC) established the Connections Reform Initiative (CRI) to address concerns with delays and increasing complexity in connections to the National Electricity Market (NEM). The CRI has noted that these rule changes are consistent with the scope of the highest priority project in its December 2021 Connections Reform Roadmap.[16]

The AEMC will consider the work that the CRI has undertaken in our assessment of the rule change requests, and will work closely with the CRI as this rule change progresses.

1.3 We have commenced the rule making process

The rule making process has been initiated by the Commission commencing consultation on the rule change proposals. Given the two rule change requests relate to the same issues, we have determined to consolidate the two rule change requests as described in section 2.2.

The Commission has extended the publication date of the draft determination to 3 November 2022.[17] This is an extension of approximately two months relative to the standard time frame, and we consider it is needed to:

- Establish a stronger evidence base by commissioning expert qualitative engineering advice and quantitative studies (if possible) to support making a rule on the amount of reactive current support that inverter-based resources should be required to provide.
- Allow staff to engage effectively with generators, network service providers, and AEMO on any change that we may make (e.g. through a technical working group), and to ensure any externally commissioned support is also consulted upon before a draft determination is published.

More information on the rule change process can be found in *The Rule change process – a guide for stakeholders.*[18]

16 Clean Energy Council. Connections Reform Initiative. https://www.cleanenergycouncil.org.au/advocacy-initiatives/energy-transformation/connections-reform-initiative.

17 See s107 notice published alongside this consultation paper.

18 *The rule change process: a guide for stakeholders, June 2017, available here: https://www.aemc.gov.au/sites/default/files/2018-09/A-guide-to-the-rule-change-process-200617.PDF*

2 MAKING OUR DECISION

When considering a rule change proposal, the Commission considers a range of factors.

This chapter outlines:

- issues the Commission must take into account;
- the proposed assessment framework; and
- decisions the Commission can make.

We would like your feedback on the proposed assessment framework considering whether the potential benefits of removing unnecessary barriers for generators connecting are outweighed by the potential additional risks to system security from making the proposed changes.

2.1 The Commission must act in the long term interests of consumers

The Commission is bound by the National Electricity Law (NEL) to only make a rule if it is satisfied that the rule will, or is likely to, contribute to the achievement of the National Electricity Objective. This is the decision-making framework that the Commission must apply.

The NEO is:[19]

> To promote efficient investment in, and efficient operation and use of, electricity services for the longer term interests of consumers of electricity with respect to
>
> (a) price, quality, safety, reliability and security of supply of electricity; and
>
> (b) the reliability, safety and security of the national electricity system.

The question to be answered in assessing any rule change proposal is therefore, would the proposed change promote more efficient decisions relating to investment, operation and use of electricity services in a way that would ultimately promote the long-term interests of consumers?

2.2 Consolidation of the rule change requests

The Commission has determined that it would be more efficient to consider rule change proposals ERC0272 and ERC0329 together as they both relate to the reactive current capability standard that should apply to inverter-based generation technology. Both rule changes relate to provisions that specify the amount of reactive current that needs to be provided in response to disturbances following contingency events.

The Commission has decided to consolidate the two rule change requests in accordance with section 93(1)(a) of the NEL and to consider them together as part of a single rule change assessment process.

19 Section 7 of the NEL.

2.3 Three criteria are guiding our assessment of the proposed rule change

In determining whether the rule change request is likely to contribute to achieving the NEO, and to assess the problem identified in this rule change request, and the proposed, or alternative solutions, the Commission proposes to focus on **security, reliability,** and **market efficiency**.

Specifically, the Commission proposes to assess whether a change to the Rules to modify the reactive current response requirements following a contingency event supports or promotes:

- **Security and reliability**— The purpose of generator performance standards such as the reactive power capability standard, is to ensure that the system is configured to allow AEMO to operate the NEM securely within acceptable levels of voltage and frequency deviation. Efficient standard-setting requires the Commission to balance the costs of meeting the standard with:
  - its benefits for system security, including the extent to which it offsets the security impacts of thermal retirements and
  - its benefits for system reliability, including the extent to which it ensures timely connection of new generation so that reliability outcomes in the NEM can be promoted.
- **Cost allocation**— Mandating access standards minimises the impact that connection applicants have on the network and improves outcomes for system security and reliability. However, imposing access standards on connecting parties also typically increases the costs they face to connect, through the installation of additional capability or additional tuning of plant parameters, which can increase costs to consumers. The Commission will seek to determine whether the current standard balances the cost of achieving system security against the broader benefits for system security and reliability and whether the standard is set in a way that minimises the complexity of the grid approvals and compliance assessment process for connecting parties, and AEMO.
- **Risk allocation** — In an efficient market, risks should be allocated to the parties best placed to manage them. In the case of a generator access standard being specified at an inappropriate level, there is a risk to system security on the low end, and of connecting parties incurring unnecessary costs on the high end.
  - The Commission will look to this principle to determine how the generator access standard should be set to minimise duplication of assets between the network and generator side.
  - The Commission will aim to do this by identifying the efficiency of the current and a revised standard by consulting on whether the party that is responsible for delivering reactive current support services has access to information that allows them to understand, respond to and manage those risks.
  - This will in turn help the Commission establish how the allocation of reactive current capability between generators and networks can preserve competition and place downward pressure on these costs over time.

- **Transparency and simplicity** — Information asymmetries often result in parties making suboptimal decisions, which may lead to inefficient expenditure and eventually, higher prices for consumers. A rule should maximise transparency and minimise complexity for all parties involved.
  - This criterion aims to ensure connecting parties have clarity on the obligations that they have to meet before connecting to the network — including what capabilities they need to demonstrate before connection approval is granted.
  - For parties who are already connected to the network — this criterion aims to help the Commission assess whether generators, NSPs and AEMO all have the same understanding of how generators will respond under a variety of voltage and frequency conditions.

In short, any rule made in response to this rule change request will be assessed on whether the amount of reactive current support that generators have to provide ensure system security needs are met at least cost. However, setting such a requirement will need to be balanced against the possible impact on consumers including from:

- investments that may need to be made by network businesses to offset under-investment in voltage support capacity
- longer-term incentives on generators to continue to identify lower-cost ways of meeting system needs such as through investment in advanced, grid following capability and/or investment in grid forming generation capacity.[20]

Changes to the connection process will also be assessed on whether they increase transparency and simplicity while maintaining the integrity of the process and ensuring generators are capable of supporting a stable and secure power system

Additionally, a rule change that meets the above criteria will support **decarbonisation** in the NEM by removing unnecessary barriers to new inverter-based technologies connecting.

QUESTION 1: ASSESSMENT FRAMEWORK

Do stakeholders agree with the proposed assessment framework? Alternatively, are there additional principles that the Commission should take into account or are there principles included here that are not relevant?

2.4 We have three options when making our decision

After using the assessment framework to consider the rule change request, the Commission may decide:

20 Grid following inverters do not contribute any system strength or assist the maintenance of a stable voltage waveform as they track or "follow" a strong voltage waveform to remain stable and synchronised to the grid. In comparison, grid forming inverters do not 'demand' system strength like grid following inverters do, and may contribute to the strength of the power system through stabilising the voltage waveform. This is because grid forming inverters create their own voltage reference and do not need a reference from the system. Grid forming inverters are an emerging technology and work is underway to further develop this technology, and integrate it into the power system.

1. to make the rule as proposed by the proponents if it will, or is likely to, contribute to the achievement of the NEO, consistent with the proposed assessment framework,
2. not to make a rule if the evidence we gather through the rule change process suggests that maintaining the status quo will, or is more likely to, contribute to the achievement of the NEO, or
3. make a more preferable rule (which may be materially different to the proposed rule) if it is satisfied that, having regard to the issue or issues raised in the rule change request, the more preferable rule will, or is likely to, better contribute to the achievement of the NEO.[21]

2.5 We may make a differential rule for the Northern Territory

The NER, as amended from time to time, apply in the Northern Territory, subject to modifications set out in regulations made under the Northern Territory legislation adopting the NEL.[22]

The majority of the proposed rule would not apply in the Northern Territory, as it amends provisions in Schedule 5.2 of the NER, which has no effect in the Northern Territory. However, the proposed rule includes changes to definitions in chapter 10 of the NER, which does apply in the Northern Territory.[23]

The Commission will therefore assess the proposed rule against additional elements required by Northern Territory legislation:

- Should the NEO test include the Northern Territory electricity systems? For this rule change request, the Commission will determine whether the reference to the "national electricity system" in the NEO includes the local electricity systems in the Northern Territory, or just the national electricity system, having regard to the nature, scope or operation of the proposed rule.[24]
- Should the rule be different in the Northern Territory? The Commission will consider whether a uniform or differential rule should apply to the Northern Territory, taking into account whether the different physical characteristics of the Northern Territory's network would affect the operation of the rule in such a way that a differential rule would better contribute to the NEO.[25]

21 NEL section 91A.

22 National Electricity (Northern Territory) (National Uniform Legislation) Act 2015 (NT Act). The regulations under the NT Act are the National Electricity (Northern Territory) (National Uniform Legislation) (Modification) Regulations 2016.

23 Under the NT Act and its regulations, only certain parts of the NER have been adopted in the Northern Territory. The version of the NER that applies in the Northern Territory is available on the AEMC website at: https://energy-rules.aemc.gov.au/ntner.

24 Clause 14A of Schedule 1 to the NT Act, inserting section 88(2a) into the NEL as it applies in the Northern Territory.

25 Clause 14B of Schedule 1 to the NT Act, inserting section 88AA into the NEL as it applies in the Northern Territory.

3 PROBLEMS RAISED BY THE RULE CHANGE PROPOSAL

Resources that wish to connect to the NEM would like network capacity to accommodate generation export. Accordingly, many connect to the extra high voltage (EHV) transmission network where they are less likely to be subject to thermal and/or voltage constraints.[26] These EHV networks are typically stronger than lower voltage networks (below 66 kV) given the former are designed for bulk power transfer, so they operate more stably when transferring large volumes of power.[27]

The wind turbine OEMs' rule change request proposes that additional dynamic reactive current support capability, which is mandated under the minimum access standard, is unlikely to provide any additional security benefits. The proponent considers that this is because these resources connect to high voltage connection points and because they typically include a large electrical balance of plant.[28]

The rule change request from RER also raises concerns as to whether the existing minimum reactive current support capability standard on asynchronous generators is aligned with locational needs. Specifically, the RER proposal notes that the existing standard leads to a level of reactive current injection and/or absorption capability that has the potential to cause rapid changes in voltage levels at the connection point that can be difficult to control.[29]

The Commission seeks stakeholder feedback on the above high-level definition of the problems raised by the rule change proponents and the following sub-sections which explore the issues in further detail.

The sub-sections explore the impact that the existing minimum reactive current standards may be having on the issues introduced in the Commission's assessment framework (see Section 2.2).

- Sub-section 3.1 explores the potential unintended impacts the minimum reactive current capability standards may be having on meeting system security and reliability objectives at the lowest cost and what reactive current capability standard (if any) should apply to emerging inverter-based loads
- Sub-section 3.2 explores the impacts on the efficient allocation of risk between networks and generators and the potential impact that this allocation may be having on competition driving down the cost of meeting system security over time

26 EHV networks are typically >110 kV.

27 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, p. 3-4.

28 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, p. 3. This internal balance of plant comprises long internal transmission lines, a medium voltage reticulation network supported by multiple collector circuits that consolidate power through multi-stage grid transformers.

29 Typically between 90% and 110% of the normal voltage at the connection point which is the range over which continuous uninterrupted operation of all operating generating units is required under NER cl. S5.2.5.4(b).

- Sub-section 3.3 explores the impacts current requirements may be having on ensuring the Rules are practical, simple to understand, and facilitate efficient connections assessment processes.

3.1 Existing reactive current standards may be creating difficulties for meeting security and reliability objectives at least cost

3.1.1 Reactive current capability standards that currently apply to inverter-based resources

The current minimum access standards require asynchronous generators to provide a minimum level of reactive power injection or absorption capability to address voltage instability following a short-duration fault.

The reactive current response requirements on inverter-based generators have four key components that require connecting generators to:

1. install a level of reactive power injection or absorption capability equal to at least 2% of the maximum continuous current of the generating system including all operating asynchronous generating units for each 1% change (reduction or increase) in voltage at the connection point above the under or over voltage range (see point 2 below).[30]
2. commence their reactive current injection or absorption response when the connection point voltage is in an under-voltage range of between 80% and 90% of the normal voltage or an over-voltage range of between 110% and 120% of the normal voltage.[31]
3. tune the control system so that the voltage response at the connection point has a rise time of no greater than 40 milliseconds (ms) and a settling time of no greater than 70 ms and for the response to be adequately damped (for reactive current response duration of 2 seconds or less).[32]
4. ensure active power recovers to 95% of the pre-fault level, 100 milliseconds after a fault clears.

These standards will also apply to bidirectional and other hybrid inverter-based resources (e.g. batteries) from 3 June 2024 following the commencement of the *National Electricity Amendment (Integrating Energy Storage Systems into the NEM) Rule 2021*.[33]

There is currently no requirement on inverter-based loads (IBL) to provide reactive current support capability to manage voltage disturbances that are caused by short-duration faults. The only access standards that currently apply to loads require them to negotiate the installation of power factor correction equipment to manage steady-state fluctuations in load that may cause downstream disturbances in voltage that harm other market participants.

The recent *National Electricity Amendment (Efficient management of system strength on the power system) Rule 2021* will introduce new access standards on inverter-based loads to

30 NER cl. S5.2.5.5(n)(1).

31 NER cl. S5.2.5.5(o)(1).

32 NER cl. S5.2.5.5(o)(2).

33 AEMC, Integrating energy storage systems into the NEM, Rule determination, 2 December 2021, p. viii.

remain connected to the electricity system down to a minimum short-circuit ratio of 3.0.[34] [35] This requirement aims to ensure that relatively minor disturbances to voltage waveforms do not lead to inverter-based loads disconnecting from the network and causing larger voltage and/or frequency disturbances that impacts the ability of other generators and/or loads to remain synchronised to the network. However, there is no requirement on inverter-based loads to inject or absorb reactive current to restore voltages to their normal range at the connection point after a short duration fault.

3.1.2 Reactive current capability minimum access standards may be leading to inefficient allocation of security and reliability costs between market participants

Both the wind turbine OEMs and RER, consider that the current minimum access standard for the level of reactive current capability that generators have to install, and the response characteristics that they have to meet, are not commensurate with locationally specific power system needs.[36]

1. The wind turbine OEMs have noted that current standards are likely to delay investment in new generation projects. These delays arise from the complexities associated with procuring, integrating and seeking connection approvals for generation and dynamic reactive power support equipment to meet the minimum access standards. Furthermore, the complexity of the approvals process increases with project size which leads to further uplifts in project costs that are ultimately passed on to customers.
2. The wind turbine OEMs have also noted that current standards require them to invest in costly balance of plant equipment that delivers little additional security benefits and instead leads to some connection applicants seeking to connect smaller less efficient generating systems to reduce the cost of demonstrating compliance with minimum access standards. However, splitting larger projects into smaller ones creates complexity in the interfaces between various parties during construction, commissioning and operation. This reduces the commercial viability of these projects and leads to higher costs that are ultimately borne by consumers in the form of higher wholesale prices.
3. Both the wind turbine OEMs and RER noted that the current minimum reactive current capability access standards may be having a detrimental impact on system security in medium and low voltage points of connection.
    a. The RER proposal noted that dynamic reactive control devices (e.g. STATCOMs and synchronous condensers) can be difficult to control and coordinate at a system level. For example, large amounts of reactive current injection in weak parts of the power system (e.g. medium, low or remote high voltage points of connection), characterised by low levels of fault current, can lead to large changes in voltages at the connection point that can then be difficult to control.[37] [38]

34 These rules come into effect from 15 March 2023.

35 AEMC, Efficient management of system strength on the power system, Rule determination, 21 October 2021, p. 125.

36 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, p. 15.

37 Rule change request from RER Pty Ltd on 2 April 2019: Maximum reactive current during a fault, p. 7.

38 Clean Energy Council, Letter to NSW Department of Planning, Industry and Environment on NSW REZ access standards intended to apply to Central-West Orana: REZ, p. 8.

b. The wind turbine OEM proposal suggests that current standards create perverse incentives for connecting generators to prioritise reactive current response over the injection of active current, particularly where controlling frequency deviations may be more important than controlling voltage within a given part of the network.[39]

RER's rule change proposal also notes that correctly aligning the level of voltage support capability that is available at a connection point during faults may improve the performance of control responses and increase the amount of generation capacity that can be installed in a particular part of the network.[40]

3.1.3 Emerging technologies may affect voltage control issues after contingency events

An issue that is relevant to the Commission's assessment of the existing reactive current capability minimum access standard and its potential impact on network voltage stability is whether large-scale inverter-based loads like electrolysers have the ability to, and should, provide reactive current following short-duration faults that lead to voltage disturbances. This is likely to be an important emerging issue as AEMO's draft ISP has forecast a significant volume of new electrolytic load to be installed as the prospects for the electricity system to contribute to the decarbonisation of the hard-to-abate industrial sectors of the economy gain momentum.[41]

Some of the largest loads to be potentially commissioned in the future are electrolysers. Electrolysers incorporate inverter-based technologies that convert AC to DC power that is then used to split water into hydrogen and oxygen. Like generators, these inverter-based loads require stable voltage levels at the connection point and a stable voltage waveform to remain synchronised to the power system and operate securely. However, unlike inverter-based generators, these loads are not currently required to provide reactive current.

If electrolysers have the capacity to provide reactive current support but do not and are exempted from any requirement to do so, there may be a risk that short duration faults could lead to voltage disturbances that risk other major loads or generators disconnecting from the power system. If these voltage instability issues are uncontrolled and increase in magnitude, there may be a risk of a steady degradation in the quality of voltage waveform and the loss of system strength in that part of the power network. This in turn may threaten stable frequency and voltage levels more broadly and further reduce the amount of inverter-based generation or load that can be accommodated in a given part of the power system.

The Commission is interested in stakeholder views regarding whether this is an accurate characterisation of the potential risk to power system stability that may result if major inverter-based loads do not provide a reactive power response to stabilise voltage levels after a fault. If electrolysers are likely to present emerging issues for secure operation of the power system, the Commission is interested in understanding how much dynamic reactive

39 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, p. 17.

40 Rule change request from RER Pty Ltd on 2 April 2019, *NEM Rule change proposal*, p. 4.

41 AEMO Draft 2022 Integrated System Plan December 2021, pp. 25-8.

control support they can or should provide to manage localised voltage instability, and what characteristics that reactive current response should have.

> QUESTION 2: HAS THE COMMISSION CHARACTERISED THE PROBLEMS CREATED BY EXISTING ARRANGEMENTS FOR SECURITY AND RELIABILITY CORRECTLY?
>
> - Are the current standards efficient? If current standards are too onerous, what impacts are the reactive current capability standards having on the viability of new resources connecting to the system? Can these impacts be quantified?
> - Can the impacts of the reactive current standards on system security be quantified? If not, under what specific circumstances do the coordination challenges presented by too much reactive current capacity create system security risks?
> - What implications might emerging technologies have for existing reactive current capability standards? What are the cost and regulatory complexity implications of emerging technologies providing reactive current to support voltage stability?

3.2 Reactive current capability minimum access standards may be leading to inefficient allocation of security and reliability costs between market participants

The generator access standards require connecting parties to provide reactive current capability that contributes to the maintenance of stable voltage levels at the connection point.[42] The reactive current capability that generators are required to provide helps to ensure stable voltages following some short duration faults.[43] In this respect, the second problem that the wind turbine OEMs proposal raises is whether these obligations enable the efficient allocation of the costs of providing reactive support between generators and network service providers. This problem was not raised in the RER rule change proposal.

The wind turbine OEMs' proposal also identified the risk that generator investments in reactive current capable equipment may become stranded, if TNSPs build scale efficient syn-cons in the same area in line with the recent system strength reform.[44] The wind turbine OEMs also note that generator minimum access standards may also cause duplicative investments in dynamic reactive power control equipment on the generator and network sides of the power system. This could occur in the future if AEMO determines that networks address a system strength deficit in a particular part of the power system and generators later connect in the same or similar location and add surplus dynamic reactive power control equipment, leading to inefficient costs being passed on to consumers.

42 NER cl. S5.2.5.5(f) and (n).

43 Schedule 5.2 also requires networks to ensure voltage levels on their network remain within 90% and 110% of normal voltages, which is the range within which generators are required to remain continuously operational.

44 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, p. 1.

To the extent that reactive support equipment has scale efficient, common use features, it may be valuable for those services to be provided by NSPs. On the other hand, generators may be better placed to make decisions to invest in equipment with more modular characteristics that directly benefit them or allows them to offset the potential harm their generating system may have on the local network.

The Commission will need to understand the types of reactive support equipment that have scale efficient characteristics that benefit a diffuse group of connecting parties and networks over a broad area and the type of equipment that have more modular characteristics, which means that it may be more efficient for generators to provide that resource by making individual locational and power plant design decisions.

The Commission needs to consider the following questions to determine the share of reactive current capability costs that should be borne by generators against those that should be borne by network businesses:

- what investments generators, network businesses and AEMO believe are needed to support stable voltage levels and power quality, and
- what cost structure do those investments have i.e. do they have scale efficiencies or is it more efficient for them to be spread across various connection sites.

Answering these questions will allow the Commission to determine whether the minimum reactive current capability access standard:

- should be zero, except in very specific circumstances, or if it
- should be set at a non-zero level, and if so what that level should be.

This approach will allow the Commission to ensure that any revision of the reactive current access standard will help preserve competitive signals where and when it is appropriate to do so. This may see generators continue to bear some of the costs of providing dynamic reactive power support in certain circumstances. The Commission is also interested in understanding the scenarios where it may be more appropriate for generators to make investments in reactive power support equipment.

QUESTION 3: HAS THE COMMISSION CORRECTLY CHARACTERISED THE PROBLEMS THAT CURRENT ARRANGEMENTS MAY BE PRESENTING FOR THE EFFICIENT ALLOCATION OF RISKS?

- Is the current allocation of responsibilities between NSPs and generators for providing voltage support services maximising system security benefits across the power system?
- If the current allocation is inefficient, what impacts or costs are current arrangements placing on generators' or network businesses' abilities to ensure a secure system at least cost?
- Can competition drive meaningful innovation that will reduce the cost of delivering voltage support services over time?

3.3 Complexity of existing minimum reactive current capability standards may be creating barriers to the efficient assessment of connection proposals

The wind turbine OEMs' rule change proposal also raised a third issue that relates to the potential impact for the connections assessments process arising from ambiguity regarding:

- the level of additional reactive current injection or absorption capability generators should have the capability to provide following a fault;
- the voltage level at which generator control systems trigger the installed reactive current response capability, and where the voltage trigger should be measured, and;
- the level of active power an inverter-based resource unit should inject after a fault clears to ensure both voltage and frequency remain within stable operating bounds.

The impact on the connections process of ambiguity in the current Rules was not raised in the RER rule change proposal.

The NER currently specify that a reactive current response is to be provided at the connection point but the wind turbine OEMs proposal notes that the reactive current response is typically determined from voltage levels recorded at the generator unit terminal. The NER deal with this issue by prescribing a range of connection point voltage levels over which a reactive current response must commence.

However, the wind turbine OEMs' proposal considers that this range creates uncertainty regarding when a reactive current injection or absorption should commence. The OEM proponents go on to note that the issues regarding the type of reactive power response that a connecting party can provide, and the conditions under which that response is provided typically only emerges through wide area power system studies that take place quite late in the connections process.

These delays can be further complicated by more advanced connection applications having to take into account the impact of other proximate generation connection applications that are at a less advanced state of development. The OEM proponent notes the implication of this is that if issues identified through these power system impact assessments are not identified and resolved before projects are commissioned, there remains a residual risk that generators will be constrained unexpectedly after they are commissioned and enter operation.[45] These risks to potential downgrades to the expected returns that projects can earn could raise the costs of generation that may be passed on to consumers in the form of higher wholesale costs.

45 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, p. 10.

QUESTION 4: MORE TRANSPARENT AND SIMPLER GRID APPROVALS

- What problems are the existing minimum access standards on reactive current presenting for more transparent and simple grid approvals?
- Can the cost of these problems be quantified in terms of the typical amount of time it currently takes for grid approvals and how much faster it could be if the Rules were simpler?

4 SOLUTIONS RAISED BY THE RULE CHANGE PROPONENT

The wind turbine OEMs' rule change request proposes the following solutions to address the issues raised.

- Resolve the potential risks to consumers from inefficient investment in system security services by lowering the generator access standard that specifies the minimum reactive current injection and/or absorption capability that asynchronous generators need to demonstrate before NSPs are able to grant connection approval (see Section 4.1)
- Resolve challenges associated with controlling and coordinating reactive power responses during faults (see Section 4.2) by:
  - shifting the point of compliance assessment from the connection point to the generator unit terminals (see Section 4.2.1)
  - specifying a fixed trigger for a reactive current response at the generator unit terminals instead of a range at the connection point in the NER currently (see Section 4.2.2)
  - relaxing the rise and settling time standards that specify how quickly voltage at the generator unit terminal needs to settle to within an acceptable level of fluctuation relative to the normal voltage (see Section 4.2.3)
- Resolve regulatory uncertainty that may be leading to inefficient delays in the connections assessment process by clarifying how quickly active power should rise to pre-disturbance levels after a fault clears (see Section 4.4) and back to a level that characterise steady state generator output.

The rule change request from RER proposes the following solution:

- Resolve the potential risks to secure system operation from the minimum and automatic reactive current capability standards not being aligned to locational power system needs by including a new definition for the maximum continuous current contributed by inverter based generators (see Section 4.1).

The following sub-sections provide a summary of the:

- proponents' rule change requests,
- our views on the key interactions between the proposed rule changes and the NER,
- matters that the Commission would like stakeholder feedback on.

4.1 What reactive current capability standard should apply to inverter-based resources?

4.1.1 The wind turbine OEMs' proposal for a revised minimum reactive current capability standard for inverter-based generators

The NER currently requires inverter-based generators to install capability to inject at least 2 per cent of the maximum continuous operating current of all asynchronous generating units (assuming no disturbance) for each 1 per cent increase or decrease in voltage at the connection point.[46] However, the wind turbine OEM rule change proponents question whether this reactive current capability standard is set at the right level, including: whether it may in fact be delivering a level of system security in excess of what is necessary, or whether the minimum capability is at a level that is detrimental to system security.[47]

The wind turbine OEMs reference the principles that guide the establishment of the automatic and minimum access standards, noting that the minimum access standard is the level of performance that would be appropriate in any location of the power system, for any connection.

This means that the minimum access standard should reflect the lowest level of performance required of a connection such that it does not adversely affect power system security or the quality of supply to network users.[48] The proponents further clarify that, in practice, this means considering the lowest level of performance that may be acceptable for a connection to do no harm in the best network conditions relevant to that technical requirement (in particular, the system strength at the proposed connection point) that are currently seen across the power system.[49]

To this end, the wind turbine OEMs' proposal has requested that the NER be changed:

1. To establish a new requirement for the capacitive or inductive reactive current capability at the connection point to be at least at its pre-disturbance level after the generating unit response has settled in accordance with S5.2.5.5(o)(1) of the NER.[50]
2. To clarify that the current response be up to the generating unit apparent current limit by requiring that the reactive current contribution is such that the total current of the generating unit may be limited to:
    a. the maximum continuous current of the generating unit during under-voltage conditions, or
    b. sufficient current to maintain rated apparent power of the generating unit during over-voltage conditions.[51]

To support these changes, the wind turbine OEMs' proposal has also requested the following new definitions be introduced to the NER Glossary (Chapter 10):[52]

1. That the maximum continuous current of the generating unit is the maximum apparent current rating of an operating asynchronous generating unit (in the absence of a

46 NER clause S5.2.5.5.(n).

47 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, pp. 16.

48 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, pp. 14-5.

49 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, pp. 15.

50 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, p. 20.

51 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, p. 20.

52 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, p. 21.

disturbance and at normal operating voltages) as measured at the generating unit terminals.

2. That the reactive current be calculated as per the method defined in IEC 61400-21:2008, whereby the positive sequence and negative sequence reactive current components of the fundamental frequency (50 Hz) are separated out.

4.1.2 RER's proposal for revisions to both the minimum and automatic reactive current capability access standard for inverter-based generators

RER's rule change request has proposed that the reactive current contribution capability, under either the automatic or minimum access standard be limited to the:

1. Maximum continuous current of a generating system, including its operating asynchronous generating units (*Existing rule in NER cl. S5.2.5.5(u)(1)*) or
2. The current listed in Table 1 (see below), for the Half-Integer X/R ratio[53] at the generating units' point of connection, where the generating system contributes the maximum continuous current of the generating system, as active and reactive current, including its operating asynchronous generating units.[54]

RER expects that solar and wind generators could be expected to see improved control in low X/R ratio grids and that no additional costs are likely to be incurred, by any parties, under the proposed wording. The new rule would allow applicants to limit the maximum reactive current (iq) to 92.85% — 99.23% of the current rating of the generating unit.

The Commission's initial assessment is that X/R ratios are of greater relevance to distribution level connections rather than transmission level connections. In a high X/R ratio grid (X/R ratios > 40), reactive power has a larger impact on voltage, but in relatively low X/R ratios active power has a larger impact on voltages. This means that too much reactive power injection in low X/R grids may cause voltage instability at the connection point that can be hard to control.

Table 1:

Table 4.1: Proposed maximum reactive current as a function of the reactance to resistance ratio at the connection point rounded to the nearest half integer.

HALF INTEGER X/R RATIO*	MAXIMUM REACTIVE CURRENT (PU)	MAXIMUM CONTINUOUS CURRENT (PU)
8.0	0.9923	1.0
7.5	0.9912	1.0
7.0	0.9899	1.0
6.5	0.9884	1.0
6.0	0.9864	1.0

53 X/R – reactance to resistance ratio. At higher voltages, X/R ratios are very high (> 40). This is because reactance in these circuits is typically very high, but resistance levels don't change markedly. In lower voltage circuits, reactance is smaller, which typically means X/R ratios are lower (X/R < 20).

54 Rule change request from RER Pty Ltd on 2 April 2019: Maximum reactive current during a fault, p. 6.

HALF INTEGER X/R RATIO*	MAXIMUM REACTIVE CURRENT (PU)	MAXIMUM CONTINUOUS CURRENT (PU)
5.5	0.9839	1.0
5.0	0.9806	1.0
4.5	0.9762	1.0
4.0	0.9701	1.0
3.5	0.9615	1.0
3.0	0.9487	1.0
2.5	0.9285	1.0
* Half integer X/R ratio defined as the reactance divided by the resistance of the network impedance observed at the point of connection of a generating system under a system normal condition, rounded to the nearest half-integer (0.5)		

Source: Rule change request from RER Pty Ltd on 2 April 2019: Maximum reactive current during a fault, p. 6.

QUESTION 5: EVIDENCE TO SUPPORT CHANGING THE POINT OF COMPLIANCE FROM THE CONNECTION POINT TO GENERATOR UNIT TERMINALS

- What factors should guide the Commission's assessment of how to determine the reactive current capability standard that should apply to inverter-based generation?
- What are the implications of limiting the minimum reactive current response capability that inverter-based generators have to provide, to the relationship proposed by RER in Table 1?

4.1.3 Setting a more efficient minimum reactive current capability access standard

The wind turbine OEM proponents have noted that the current minimum reactive current access standard requires generators to both install and tune STATCOM or synchronous condensers close to the connection point to meet the response capability and rise and settling time standards. The OEM proponents consider that the costs of designing, installing and commissioning this equipment ultimately worsens project economics, particularly if the equipment is not serving any additional purpose such as steady-state reactive power control or in remediating system strength.[55]

The proponent also considers that the requirement to provide this reactive current capability at the connection point may not be appropriate and may be of little benefit if the reactive current support that generators provide at the terminals is already sufficient given network conditions. In these circumstances, the proponent has advised that the generator access standards may duplicate investments on the generator and network sides that ultimately increase costs for consumers and pass on inefficient costs to end users.

55 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, p. 18.

The wind turbine OEM proponents subsequently go on to advise that generation project proponents have tried to address these commercial viability challenges by dividing larger projects into smaller ones with multiple connection points. However, this approach while attractive from a technical perspective introduces significant complexity in the interfaces between various parties during construction and operations and thus reduces the commercial viability of generation projects.[56]

Through the 2018 GTPS rule change process, stakeholders provided the AEMC feedback that the current minimum response capability may be excessive under weak fault level conditions. Some stakeholders considered that the current standard may lead to inefficient investment in auxiliary reactive plan that is not necessary.[57] This has been reinforced recently by the Clean Energy Council and their members but what is unclear is what level the reactive current standard should be reduced to. For instance, some CEC members have noted that there should be no reactive current requirement whereas others have advised that the reactive current capability standard should be aligned to what generator unit terminals are already capable of.[58]

QUESTION 6: WHAT SHOULD THE MINIMUM REACTIVE CURRENT CAPABILITY BE?

- If the point of compliance remains at the connection point, at what level should the minimum reactive current capability that generators have to install be set?
- What potential risks to system security are there from lowering the minimum reactive current capability to this level?
- What are the potential benefits for reliability and efficient investment in generation from lowering the reactive current capability?

4.1.4 A minimum access standard that is too high may lead to investment duplication on the generation and network sides

Investments in the same or similar system support services in the same areas could arise through obligations created by the AEMC's recent *Efficient management of system strength on the power system* rule. The rule created new obligations on TNSPs to provide an efficient level of system strength to support the connection of inverter-based resources (IBR) forecast by AEMO. This standard will be developed based on the:

- Forecast of efficient future IBR connections for each system strength node (that will need to be identified by AEMO through the modelling undertaken as part of the ISP)
- Three phase fault level required for a secure system at each node.

56 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, p. 18.

57 AEMC, Generator technical performance standard, Rule determination 27 September 2018, pp. 165-6.

58 Clean Energy Council, Letter to NSW Department of Planning, Industry and Environment on NSW REZ access standards intended to apply to Central-West Orana: REZ, p. 8. See: https://assets.cleanenergycouncil.org.au/documents/advocacy-initiatives/submissions/submission-nsw-rez-access-standards-consultation-package.pdf

AEMO is yet to determine both the location and spread of these nodes across the power system and how much system strength will need to be provided to support the connection of a given amount of inverter-based generation capacity. Meeting the system strength standard will typically require system strength service providers (typically TNSPs) to make investments in synchronous generators or condensers, and other reactive equipment to help support stable voltage levels.

The wind turbine OEM proponent has advised that retaining the current minimum access standard for reactive current response may result in a duplication of investments on the network and generation sides and could lead to stranded assets.[59] [60] To provide an indication of scale, the proponent has advised that the design, supply and install costs for a STATCOM system[61] of a size needed for a large wind farm can be in the order of $30 – 45 million.[62] The proponent notes that these costs may lead to certain projects not delivering acceptable commercial returns, which may delay investment. Alternatively, these investments may also duplicate investments by TNSPs that ultimately get passed on to consumers in the form of higher wholesale electricity and network charges.

The recent Clean Energy Council (CEC) submission to the NSW REZ access standards consultation advised of an approach to resolve this issue. It noted that the current minimum access standard should not apply where multiple generators in a given region need to install reactive plant behind a connection point as a more centralised solution may be more scale efficient. However, the CEC submission was not clear on the question of at what level of reactive current provision does scale efficient investment in such capacity deliver a lower cost outcome for consumers.[63]

The Commission notes that there is some uncertainty in relation to the geographic and temporal overlap between investments that are made by TNSPs to provide reactive current support to ensure a stable voltage waveform and those made by generators to ensure stable voltage levels at or near their connection point. Determining the implications of the *efficient management of system strength* rule on generator access standards will require the Commission to establish:

- the nature and cost structure of investments that networks may make
- the implications of lowering the generator access standard for system strength investments that TNSPs may be required to make in the future.

59 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, p. 16.

60 Clean Energy Council, Letter to NSW Department of Planning, Industry and Environment on NSW REZ access standards intended to apply to Central-West Orana: REZ, p. 2. See: https://assets.cleanenergycouncil.org.au/documents/advocacy-initiatives/submissions/submission-nsw-rez-access-standards-consultation-package.pdf

61 A STATCOM is a type of fast-acting voltage management device that is only capable of generating reactive power and relies on power electronic converter technology.

62 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, p. 15.

63 Clean Energy Council, Letter to NSW Department of Planning, Industry and Environment on NSW REZ access standards intended to apply to Central-West Orana: REZ, p. 8. See: https://assets.cleanenergycouncil.org.au/documents/advocacy-initiatives/submissions/submission-nsw-rez-access-standards-consultation-package.pdf

> QUESTION 7: WHAT ARE THE BENEFITS OF ALIGNING REACTIVE CURRENT CAPABILITY TO LOCATIONAL SYSTEM STRENGTH NEEDS?
>
> - To reduce the risk of investment duplication, should the minimum level of reactive current capability take into account the available / forecast level of dynamic voltage support from System Strength Service Providers?
> - What are the potential implications for the future development of grid forming inverters from lowering the minimum reactive current capability that inverter-based generators have to provide?

4.2 Changing the point of compliance assessment for the reactive current response

The wind turbine OEMs' rule change proposal has also requested that the point of compliance assessment be changed from the connection point to the terminals of inverter-based generators. This is because the current requirements are too onerous for large generating systems with large internal reticulation networks and may be undermining good control tuning necessary to suit local power system conditions The proponents also note that a fixed figure for rise and settling times does not reflect the physical differences across projects and that such a technical requirement is best suited as a factory type test rather than as a fixed requirement across all network locations.[64]

The wind turbine OEMs note that demonstrating compliance with the reactive current minimum access standard at the connection point requires generation project proponents to make balance of plant investments near the connection point that worsens project economics.[65] However, the Commission notes that the current standard was put in place to account for the risk of reactive current being attenuated through internal networks, such that little or no reactive power support is provided at the connection point.This is a particular issue for large wind farms that have generating units distributed over a large area and hence have very large internal reticulation systems.

The OEMs' proposal further notes that the over-investment in reactive current capability under the current standard seems to be an unintended consequence of the AEMC's decision in the 2018 rule change consultation process to require compliance to be measured at the connection point rather than the generating unit terminals.[66] The AEMC made a decision to change the point of compliance assessment to the connection point from the draft to the final determination in 2018 to ensure this requirement was consistent with compliance for other access standards which also applied at the connection point. The Commission supported its

64 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, p. 9.

65 Synchronous condensers are a type of reactive power generator that can either generate or absorb reactive power to/from the power grid and maintain the terminal voltage within limits.

66 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, p. 9.

decision by also noting that compliance assessment at the generator unit terminal would be more expensive because it would necessitate investment in high-speed metering at each unit within a generating system.[67]

The NER currently provide that the reactive current response can be measured at the generator unit terminals with generators being provided the flexibility to measure the response at the connection point rather than at the unit terminals. The Commission made this rule in 2018 by acknowledging that inverters (under high or low voltage ride through modes) respond to voltage levels measured at the inverter terminals rather than connection point measurements.[68] So, flexibility to measure and provide a response based on voltage deviations at the connection point was retained if generation plant operators considered that to be appropriate.

The OEMs' proposal agrees that there may be benefits in measuring compliance at the connection point. However, the proponents suggest that the Commission consider the distinction between steady state compliance and dynamic response that generation control systems provide. This is because demonstrating that generators can meet the minimum access standards through the connections process requires simulation and prediction of the dynamic response of generating units, which is best undertaken at unit terminals.[69]

QUESTION 8: EVIDENCE TO SUPPORT CHANGING THE POINT OF COMPLIANCE FROM THE CONNECTION POINT TO THE GENERATOR UNIT TERMINALS

- What are the distinctions between steady-state compliance and dynamic response that the Commission needs to consider in assessing whether to change the point of compliance assessment from the connection point to the generator unit terminals?
- What specific implications does this have for the connections assessment process and does this outweigh the cost of high-speed monitoring that is needed at each unit terminal to assess compliance?

4.2.1 Would a fixed trigger for reactive current response reduce regulatory uncertainty in the grid approvals process for inverter-based generators?

The wind turbine OEMs' rule change proposes that NER cl. S5.2.5.5(o) be replaced with a requirement that the response be based on a fixed trigger at the generating unit terminals instead of an under or over voltage range expressed as a proportion of the normal voltage measured at the connection point. The NER currently specify a range of voltages at which the reactive current response is triggered because of uncertainty in the relationship between generating unit terminal voltages and connection point voltage.[70]

67 AEMC, Generator technical performance standard, Rule determination 27 September 2018, pp. 164-5.

68 AEMC, Generator technical performance standard, Rule determination 27 September 2018, pp. 182.

69 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: *Reactive current response to disturbances (clause S5.2.5.5)*, p. 13.

70 This uncertainty arises from attenuation of reactive current response through the often long internal reticulation systems that connect various generating units across large wind farms, and the errors created by delays in connection point measurements being relayed to the power plant control system.

Specifically, the OEMs' proposal has requested S5.2.5.5(o) be changed to require that:

- Each operating asynchronous generating unit within the generating system must start its response when the voltage at the generating unit terminals drops below a fixed low voltage ride through (LVRT) threshold for an under-voltage condition or exceeds a fixed high voltage ride through (HVRT) threshold for an over-voltage condition.
- The LVRT and HVRT voltage thresholds are to be agreed with the NSP and AEMO within an under-voltage range of 80% and 90% of the voltage at the generating unit terminals and an over-voltage range of 110% and 120% of the normal voltage measured at the generating unit terminals.

The wind turbine OEMs have further suggested that this rule is supported by the typical operating procedures for most modern, commercially available inverter-based generation technologies, because:

- over the course of a fault and for a short period after fault clearance, the voltage control is performed locally and independently of the connection point measurements and the power plant controller.[71]
- low voltage ride-through logic, which determines the amount of reactive current that needs to be injected after a fault, is based on voltage measurements made at the generating unit terminals.[72]

QUESTION 9: WHAT CHALLENGES DOES THE CURRENT VOLTAGE TRIGGER RANGE PRESENT FOR INVERTER-BASED GENERATORS IN MEETING THE EXISTING REACTIVE CURRENT CAPABILITY MINIMUM ACCESS STANDARD?

- What are the implications for generator connection applicants of maintaining the rule that the response be triggered at a range of connection point voltages?
- What other implications might lowering the minimum reactive current capability that generators are required to provide have for the voltage level or range that triggers a generator's reactive current response?

4.2.2 Would making the rise and settling time standards less onerous make for a simpler grid approvals process for inverter-based generators?

The wind turbine OEMs propose changing the rise and settling time standards that are currently assessed at the connection point to the generator unit terminals.[73] The OEM's rule change proposal also proposes that the current standards that apply to responses shorter than 2 seconds be relaxed, so that the reactive current response:

71 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: Reactive current response to disturbances (clause S5.2.5.5), p. 8.

72 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: Reactive current response to disturbances (clause S5.2.5.5), p. 8.

73 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: Reactive current response to disturbances (clause S5.2.5.5), p. 8.

- has a rise time of no greater than 80 milliseconds (ms) (currently 40 ms at the connection point), and
- a settling time of 110 ms (currently 70 ms at the connection point).

The OEMs’ rule change proposal notes that existing requirements for the response to be adequately damped be retained.

The current minimum access standard requires compliance to be assessed at the connection point but the proponent notes that the current response standard is not reflective of the type of fault (balanced or unbalanced), fault severity, or the pre-disturbance operating conditions.[74] The OEMs’ proposal further notes that the current rise and settling time standards do not account for other physical differences across projects including the impact of the size of internal reticulation systems across different wind farms and the type of measurement technique that is used to detect the type of fault that has occurred (i.e. positive sequence, negative sequence or three phase). The proponent notes that this can mean that it is difficult to co-optimise the design of the generation system to meet the reactive current capability and rise and settling time standards.[75]

The OEMs’ proposal further notes that the difference between voltage levels at the connection point and the generating unit terminal means that there is a delay between when the generating units sense faults, fault severity, and provides the required response. Hence, the proposed increase in the rise and settling time requirements account for the one to two cycle (20-40 ms) delay associated with measurement of key variables, where AEMO and the NSP require the generating units to sustain a response of 2 s or less.[76]

QUESTION 10: WHAT ARE THE KEY ISSUES WITH THE RISE AND SETTLING TIME STANDARDS?

- What stakeholder experiences over the past three years support a Commission decision to revise the current rise and settling time access standards?
- What should the rise and settling time be revised to if the point of compliance assessment is maintained at the connection point instead of the generator unit terminals?
- How should the rise and settling time standards change with the minimum reactive current response capability, if at all?

74 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: Reactive current response to disturbances (clause S5.2.5.5), p. 9.

75 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: Reactive current response to disturbances (clause S5.2.5.5), p. 9.

76 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: Reactive current response to disturbances (clause S5.2.5.5), p. 20.

4.3 Resolving potential conflicts between active and reactive power response obligations to ensure frequency and voltage remain in respective normal operating ranges

The wind turbine OEMs' proposal has raised a concern that while the NER specifies a requirement to establish and respond to reactive current contribution during a fault in addition to pre-disturbance values, the Rules do not specify circumstances where active current provision should be prioritised over reactive current.[77] The OEMs' proposal notes that the reactive current minimum access standard is creating incentives for generators to tune their fault response to maximise reactive current and that this may not be appropriate in all circumstances given active power may be needed to balance frequency in the connecting network.[78]

The minimum access standards currently require inverter-based generation units to return to at least 95% of the pre-fault active power output, after fault clearance in a time period agreed by the connection applicant, AEMO and the NSP.[79] The automatic access standard establishes a fixed active power recovery obligation of 100 ms on all generators but the minimum access standard can be negotiated between NSPs AEMO and generators.

QUESTION 11: HOW SHOULD THE MINIMUM ACCESS STANDARDS THAT APPLY TO ACTIVE POWER RECOVERY BE CLARIFIED?

- Is there a conflict between the obligations for active power recovery after fault clearance to ensure stable frequency levels and the obligations in S5.2.5.5 for active power to recover to 95% of pre-fault levels after a fault occurs?
- How should this conflict be clarified to ensure clarity on generators' obligations to return to continuous uninterrupted operation in a timely manner?

77 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: Reactive current response to disturbances (clause S5.2.5.5), p. 10.

78 Rule change request from GE International Inc, Goldwind Australia, Siemens Gamesa Renewable energy, Vestas Australia on 11 March 2021: Reactive current response to disturbances (clause S5.2.5.5), p. 10.

79 NER cl. S5.2.5.5(n)(2).

5 IMPLEMENTATION CONSIDERATIONS

The Commission recognises that any change to the minimum access standards that specify the nature of reactive current support inverter-based generators have to provide will be complex. This chapter seeks stakeholder feedback on the following implementation considerations, if there are changes to the standard.

1. What are the specific transitional issues we should consider when determining whether to make a rule?
2. How can we ensure that a rule (if made) does not exacerbate issues with the connections assessment and/or compliance monitoring processes?

The Commission understands that any revisions to the minimum access standard need to provide a transitional period that accounts for the time AEMO and connection applicants may need to understand how the standards may impact system security across the grid, develop new guidelines and assessment frameworks, and new or updated compliance monitoring procedures.

Equally, the Commission also understands from stakeholders that one of the key issues with current performance standards is that it is difficult to design a power generating system that simultaneously satisfies all access standards. Therefore, making changes to reflect the reality of how a generator can and should respond to a voltage disturbance, may address some current issues that:

- Make it harder for connection applicants to tune generator capabilities to meet standards that are pulling in different directions
- Enable AEMO and NSPs to more efficiently assess applications — by reducing rework and inconsistent negotiation and assessment approaches across regions.
- Enable AEMO and NSPs to more efficiently monitor compliance with generator performance standards — as they will be able to gain a better understanding of generator capability and the circumstances under which a response can be expected.

Bringing the new standards into effect quickly may be one way to resolve the friction created by the above issues for the connections assessment process. This may then resolve uncertainties that delay the connection approvals process and resolve some of the key challenges and points of pain for generation project proponents, NSPs and AEMO.

QUESTION 12: IMPLEMENTATION CONSIDERATIONS THAT THE COMMISSION SHOULD TAKE INTO ACCOUNT

- How quickly should any new access standards come into effect?
- What are the potential unintended consequences of bringing these into effect immediately (e.g. for new connection applications)?

- What are the implications of providing project proponents the option to connect under the existing or the new standard (e.g. for advanced projects that have already been approved or close to securing grid approvals)?

6 LODGING A SUBMISSION

Written submissions on the rule change request must be lodged with Commission by 23 June 2022 online via the Commission's website, www.aemc.gov.au, using the "lodge a submission" function and selecting the project reference code ERC0272.

The submission must be on letterhead (if submitted on behalf of an organisation), signed and dated.

Where practicable, submissions should be prepared in accordance with the Commission's guidelines for making written submissions on rule change requests.[80] The Commission publishes all submissions on its website, subject to a claim of confidentiality.

All enquiries on this project should be addressed to Ashok Kaniyal on ashok.kaniyal@aemc.gov.au.

80 This guideline is available on the Commission's website www.aemc.gov.au.

ABBREVIATIONS

AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
Commission	See AEMC
HVRT	High voltage ride through
IEC	International Electrotechnical Commission
LVRT	Low voltage ride through
MAS	Minimum access standard
MCE	Ministerial Council on Energy
NEL	National Electricity Law
NEO	National electricity objective
NER	National electricity rules
NERO	National energy retail objective
NGL	National Gas Law
NGO	National gas objective
NSP	Network service provider
OEM	Original equipment manufacturer
STATCOM	Static synchronous compensator

A APPENDIX 1

A.1 Why are active and reactive power important to stable power system operation?

A.1.1 Active power

The ability of a generating system to control its active power output is relevant to the control of the frequency of the power system. An inability to control active power can also lead to changes in power flows. This can cause frequency instability, exceedance of equipment loading limits, voltage instability and system security issues. Certain capabilities to control active power are needed to be able to offer frequency control ancillary services (FCAS), which are paid market services to assist with the control of frequency on the power system.

The NER currently require all generating systems to have the capability to operate in frequency response mode. Requiring generators to record this capability in performance standards will allow generators to more quickly complete the process of becoming an FCAS provider, where they wish to do so in response to FCAS market prices. Mandating this capability will impose minimal costs on connections and is also likely to support system security.

A.1.2 Reactive power

Reactive power is the product of voltage and reactive current. Under fault conditions, voltage can rapidly fall to very low levels. As a result, a generating system's response cannot be characterised in terms of reactive power injected or absorbed, but can be characterised in terms of the amount of reactive current. It is therefore appropriate for voltage support obligations during disturbances to require a reactive current response from a generating system.

Reactive current response during a disturbance by an inverter-connected generating system is controlled by the power electronics used in the inverter and its corresponding control system. Modern inverters are equipped with what are known as 'fault ride through' modes that can provide fast-acting reactive current response during disturbances. Fault ride through modes include high-voltage ride through (HVRT) and low-voltage ride through (LVRT) modes that help generators stay connected to the network during faults. These modes typically also come with reactive current response capability, that during disturbances, help address the system security risks of short-term voltage instability and voltage collapse.

While modern inverter connected plant is capable of providing reactive current response during faults, this inverter controlled response is different to the intrinsic physical response from synchronous generating systems. Inverter controls require specific settings to determine response characteristics, such as response magnitude, speed and trigger thresholds. So, the nature of the reactive current response from an asynchronous generating system is fundamentally a property of the settings of its control systems (i.e. the algorithms in the software). This distinguishes the response of inverter-based systems to synchronous systems that provide an uncontrolled physical reaction to fault conditions due to the electromechanical characteristics of the equipment.

The reactive current response characteristics of asynchronous generating systems are also affected by the overall generating system control architecture. The system control architecture describes the relationship between generating system level power plant control (PPC) and the local control embedded in each wind turbine or solar PV inverter. The PPC acts as the 'brain' that centrally co-ordinates the response of each element of the generating system. It does this by reading measurements from the connection point (and other locations within the generating system) and sending instructions (active and reactive power set points) out to all the inverters it controls. PPC based control is referred to as 'closed loop'. However, when the generating system goes into 'ride through mode' due to a fault, each inverter individually takes over control of its own response. In this case, each inverter locally measures and responds to changes in voltage. This is because PPC based control operates on a much slower time interval than inverter level control.