Power System Oscillations in South Australia on 23 June 2022

February 2023

Reviewable Operating Incident Report under the National Electricity Rules

Important notice

Purpose

AEMO has prepared this report in accordance with clause 4.8.15(c) of the National Electricity Rules, using information available as at the date of publication, unless otherwise specified.

Disclaimer

To inform its review and the findings expressed in this report, AEMO has been provided with data by registered participants as to the status or response of some facilities before, during and after the reviewable incident, and has also collated information from its own observations, records and systems. AEMO has made reasonable efforts to ensure the quality of the information in this report but cannot guarantee its accuracy or completeness. Any views expressed in this report are those of AEMO unless otherwise stated and may be based on information given to AEMO by other persons.

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Incident classifications

Classification	Detail
Time and date of Incident	23 June 2022 0109 hrs
Region of incident	South Australia
Affected regions	South Australia
Event type	Other causes – human error – coding error introduced during testing
Generation impact	None
Customer load impact	None
Associated reports	None

Abbreviations

Abbreviation	Term
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AEST	Australian Eastern Standard Time
CB	Circuit Breaker
DER	Distributed energy resources
DNSP	Distribution network service provider
DPV	Distributed photovoltaic
HPPC	Hybrid Power Park Controller
IBR	Inverter-based resources
kV	Kilovolt/s
MVAr	Megavolt-amperes reactive
MW	Megawatt/s
NEM	National Electricity Market
NER	National Electricity Rules
NSP	Network service provider (covering both DNSPs and TNSPs)
PAREP	Port Augusta Renewable Energy Park
PoC	Point of connection
p.u.	Per unit
SAPN	South Australia Power Networks
TNSP	Transmission network service provider

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1 Overview

This report relates to an incident that occurred on 23 June 2022 involving voltage and reactive power oscillations observed in South Australia from 0109 hrs to 0602 hrs.

Following the event, Iberdrola[1] confirmed that oscillations in reactive power originated from the Port Augusta Renewable Energy Park (PAREP)[2]. The original equipment manufacturer (OEM) subsequently identified the root cause of the voltage and reactive power oscillations as relating to human error. While commissioning was being carried out, specifically during a communication fail-safe test, an error was introduced into PAREP's control system code, causing the reactive power output of the generator to oscillate. The peak-to-peak magnitude of reactive power oscillations reached a maximum of 247 megavolt-amperes reactive (MVAr), with oscillations persisting for almost five hours.

AEMO considers that this incident is of significance to the overall operation of the power system and consequently qualifies as a *reviewable operating incident* under clause 4.8.15(a)(3) of the National Electricity Rules (NER)[3]. As such, AEMO is required to assess the adequacy of the provision and response of facilities and services and the appropriateness of actions taken to restore or maintain power system security[4].

This report has been prepared in accordance with NER 4.8.15(c). It is based on information provided by Iberdrola, Vestas Australia, ElectraNet[5], Neoen Australia, AGL Energy, Tilt Renewables, Enel Green Power, Nexif Energy, Energy Australia and AEMO.

National Electricity Market (NEM) time (Australian Eastern Standard Time [AEST]) is used in this report.

AEMO has concluded that:

1. The root cause of voltage and reactive power oscillations was associated with human error, whereby incorrect control system code was applied at PAREP following a communications fail-safe test at 2000 hrs on 22 June 2022 (approximately five hours prior to the event).
2. At no point during this incident were transmission system voltages outside of relevant voltage limits.
3. Given ElectraNet's action to disconnect PAREP, no action was required by AEMO to restore or maintain power system security during the incident. The power system oscillations did not impact power system frequency and the Frequency Operating Standard was met during this incident.
4. This incident did not include any non-credible contingency events, therefore AEMO correctly identified that no reclassifications were required.
5. As this incident occurred at night, the response of distributed photovoltaic (DPV) systems was negligible, but AEMO was able to assess residential battery behaviour. One battery manufacturer identified that an external device, which is part of the manufacturer's typical battery system configuration, caused the disconnection of 95% of its residential battery fleet. The devices' event recordings indicate that the measurement of frequency

[1] Iberdrola Australia Energy Markets Pty Limited is the registered generator for Port Augusta Renewable Energy Park.

[2] PAREP is an integrated 210 megawatts (MW) wind farm and 99 MW solar farm hybrid generating system with a maximum generating capacity of 270 MW located in Port Augusta in South Australia.

[3] AEMO must review any power system events that it considers of significance to the operation of the power system, including recurring minor incidents of this type, consistent with the Reliability Panel Guidelines for identifying Reviewable Operating Incidents (dated 29 September 2022), paragraph 6(f), available at https://www.aemc.gov.au/sites/default/files/2022-09/Final%20guidelines.pdf.

[4] See NER 4.8.15(b) and (c).

[5] ElectraNet is the TNSP for South Australia

by the external device may have been affected by the distortion of the voltage waveform caused by oscillations on the power system. AEMO has discussed potential solutions with the manufacturer, such as shifting the functionality from the external device to the battery's inverter, until a new generation of product is available.

Based on the findings, AEMO makes the following recommendations:

1. Generator operators have procedures in place to ensure that, when generator or power system instability is identified, appropriate actions can be taken within a reasonable timeframe. These actions could include advising AEMO and network service provider (NSP) control rooms of the instability, investigation of the instability to determine if the generator is contributing, and, if required, disconnection of the generating facility.
2. AEMO is currently consulting with industry on guidelines for how generators can best comply with NER S5.2.5.10 (protection to trip for unstable operation) for asynchronous generators[6]. AEMO will consider a strategy for engaging further with existing proponents once these guidelines are updated.
3. As part of the access standards review[7], for new connections, AEMO is currently engaging with industry on the suitability of the requirements of NER S5.2.5.10 (protection to trip plant for unstable operation), with a focus on asynchronous generators. As part of this engagement, AEMO will consider amendments to the access standards for generators to:
    - 3.1. Monitor for instability and alert generator operators, the NSP and AEMO.
    - 3.2. Determine their contribution to system instability.
    - 3.3. Trip or ramp down under critical system conditions where the system is unstable and/or where a generator identifies itself as a high contributor to the identified system instability.
4. Consistent with recommendations relating to the West Murray Zone power system oscillations event on 16 November 2021, AEMO recommends that an acceptable oscillations limit is developed in conjunction with suitable operational tools and installation of adequate high-speed monitors to support control room operators in managing future oscillation events on the power system. This will enable operators to monitor and effectively manage oscillations within operational timeframes, and involves the following recommended steps:
    - 4.1. AEMO, in conjunction with transmission network service providers (TNSPs), to improve high speed monitoring capabilities and implement visualisation tools providing system operators with real-time information needed to respond if automatic protection systems fail to disconnect the affected generation. For more information on this recommendation, see Section 3.1 of this report.
    - 4.2. The Power System Security Working Group (PSSWG) to define a level of power system oscillations which may be considered acceptable for secure power system operation in the operational timeframe, which may be used to support TNSPs when providing operational limits advice.
    - 4.3. All TNSPs to provide AEMO with updated limit advice (where required) consistent with the acceptable level of oscillations, and identify operational actions that AEMO can take if available monitoring indicates power system oscillations exceeding the acceptable level.
5. Through this event, AEMO identified areas within the current Australian Standards (AS/NZS4777.2:2020) that require clarification related to the testing, performance, and use of external devices that could affect the performance of DPV and household battery system inverters. AEMO is currently seeking to clarify

[6] For more information, see https://aemo.com.au/consultations/current-and-closed-consultations/ner-s52510-guideline-consultation.

[7] For more information, see https://aemo.com.au/consultations/current-and-closed-consultations/aemo-review-of-technical-requirements-for-connection.

requirements within the Australian Standards (AS/NZS4777.2:2020) related to devices external to household inverters which can impact overall system performance.

6. Noting recent issues that have occurred during generator commissioning, AEMO recommends that generators review commissioning procedures to ensure controls are in place, including post-test checks and continuous monitoring during the commissioning process. In addition, when reviewing new test plans, AEMO will consider the findings of this report and (where appropriate) request that test plans include additional controls to mitigate potential risks that may arise during commissioning.
7. AEMO is currently reviewing generator commissioning requirements and will consider the findings and recommendations of this incident as part of that review[8].
8. In the 2023 General Power System Risk Review, AEMO plans to consider risks of a similar event occurring during a daytime period where a large amount of DPV is disconnected due to power system oscillations.

2 The incident

2.1 PAREP details

PAREP is an integrated wind and solar facility consisting of a 210 megawatts (MW) wind farm and 99 MW solar farm, and a total registered capacity of 270 MW. The overall facility is being registered in stages, with only the wind farm component registered (and undergoing commissioning) at the time of the incident. PAREP is connected to the Davenport 275 kilovolts (kV) substation, south-east of Port Augusta in South Australia (see Figure 5 in Appendix A1).

2.2 Pre-event conditions

On 22 June 2022, with PAREP was operating in voltage control mode[9], the wind turbine OEM completed a communication fail-safe test on the generating system park controller. The purpose of this test was to confirm the generator's communication fail-safe strategy during primary and fallback power meter failure events in accordance with the agreed commissioning plan. Appendix A2 provides additional details regarding the control sequence of the communication fail-safe strategy.

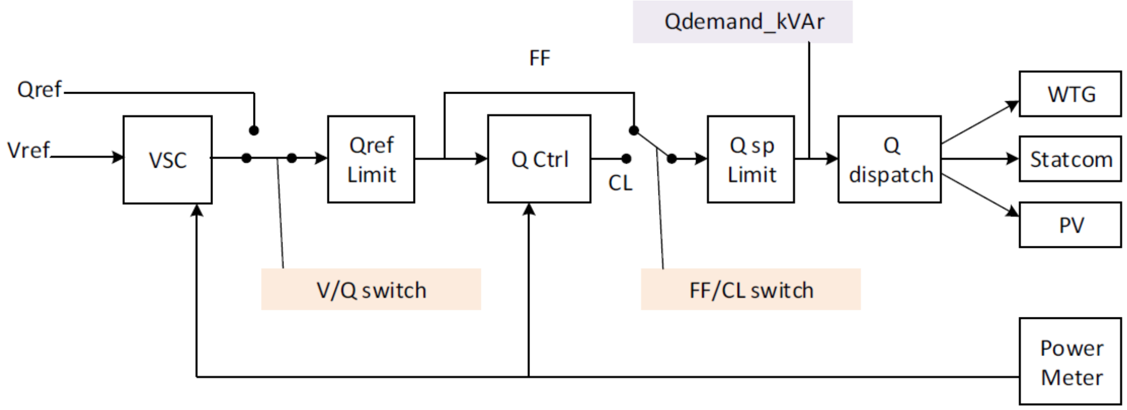
To ensure predictable and stable operation during the test, the outer control loop was changed from voltage control 'Vref' to reactive power control 'Qref' and the generator control system's inner reactive power control loop was bypassed by setting it to feed forward 'FF' mode. The communication fail-safe test was completed at approximately 2000 hrs on 22 June 2022. The control system code that was introduced by the wind turbine OEM staff during the communication fail-safe testing was incorrect, because it was missing the functionality to revert the control system automatically to its normal operating mode. Following the completion of the test, the logic in the code, due to the error, did not revert the inner control loop to closed loop 'CL' reactive power control but continued

[8] See https://aemo.com.au/-/media/files/electricity/nem/network_connections/transmission-and-distribution/generating-system-test-template-for-non-synchronous-generation.docx?la=en and https://aemo.com.au/-/media/files/electricity/nem/network_connections/transmission-and-distribution/generating-system-test-plan-template-for-conventional-synchronous-machines.pdf?la=en.

[9] In normal operation, the outer control loop mode is set to voltage control model and the inner reactive power control loop is set to closed loop (CL) mode.

to remain in feed forward 'FF' configuration with outer control loop being returned to voltage control 'Vref' (see Figure 1).

Figure 1 High level voltage and reactive power control block diagram of PAREP's park controller



2.3 The incident

Post incident analysis has confirmed that at approximately 0109 hrs on 23 June 2022, small but gradually increasing voltage and reactive power oscillations started at the PAREP point of connection (PoC). At approximately 0235 hrs, following conversations with customers (including major industrial customers) and SA Power Networks (SAPN[10]), ElectraNet became aware of a system disturbance.

From 0209 hrs to 0430 hrs, the voltage and reactive power oscillations continued to increase in size, with a recorded maximum of 247 MVAr peak-to-peak at the PoC of PAREP at approximately 0430 hrs. ElectraNet could not locate the exact source of the oscillations, as they appeared widespread throughout the network. ElectraNet initially determined that Mount Millar Wind Farm was the likely cause, and therefore recommended its output be reduced to zero at approximately 0540 hrs. Despite this action, oscillations continued to be observed.

ElectraNet staff then noticed varying unstable active power readings from the PAREP connection on their energy management system display. In response, ElectraNet opened the circuit breakers (CBs) at Davenport 275 kV substation to de-energise PAREP at 0602 hrs. The voltage and reactive power oscillations ceased when PAREP was de-energised.

Post incident analysis confirmed that reactive power oscillations lasted for approximately five hours from the first measured occurrence until ElectraNet disconnected PAREP at 0602 hrs. Table 1 shows the sequence of events.

Table 1 Sequence of events

Date	Time	Event
22 June 2022	**2000 hrs**	PAREP communication fail-safe test was completed. Following the test, the control system was not returned to correct operating state.
23 June 2022	**0109 hrs**	Small reactive power oscillations were observed in South Australia.
	0114 hrs	Large reactive power oscillations were observed in South Australia.
	0540 hrs	Output of the Mt Millar wind farm was reduced to zero. Power system oscillations continue.
	0602 hrs	CBs at Davenport substation were opened to disconnect PAREP – power system oscillations ceased.

[10] SAPN is the DNSP for South Australia

Date	Time	Event
	1050 hrs	PAREP was re-energised but was not allowed to generate.

2.4 Analysis

The following section is based on the information provided by the relevant participants (listed in Appendix 0). This section summarises analysis into the root cause and the behaviour of the reactive power and voltage on the network during the incident.

2.4.1 Root cause

AEMO's investigation has confirmed that prior to the wind turbine OEM's communication fail-safe testing, PAREP was satisfactorily operating in voltage control mode.

In normal operation, the outer control loop mode is set to voltage control and the inner reactive power control loop is set to closed loop 'CL' mode. To satisfactorily complete the required communication fail-safe testing, the outer control loop mode was changed from voltage control 'Vref' to reactive power control 'Qref' and the inner control loop mode was switched to feed forward 'FF' mode from closed loop 'CL' mode. This configuration essentially bypasses the closed loop 'CL' voltage and reactive power control and enables open-loop reactive power control mode to safely ramp down PAREP's reactive power to zero until it is safe to restart the wind farm. This change allows proper testing of the generator's performance for a sustained communication failure.

The control system code that was introduced by wind turbine OEM staff during the communication fail-safe testing was incorrect, because it was missing the functionality to revert the inner control loop from feed forward 'FF' control mode to closed loop 'CL' reactive power control for normal operation. Therefore, once the communication fail-safe testing was completed, the outer-control loop was returned to voltage control, but the inner reactive power control loop was incorrectly left in feed forward 'FF' mode. This control configuration led to instability due to the absence of closed loop 'CL' reactive power control in the inner control loop.

PAREP confirmed that the root cause for voltage and reactive power oscillations was human error which resulted in the above code error being introduced to the PAREP site-specific control system logic.

Following the completion of communication fail-safe testing around 2000 hrs on 22 June 2022, PAREP operated without any oscillations for approximately five hours.

Post incident analysis shows that around 0109 hrs on 23 June 2022, a disturbance was seen on the PAREP PoC. Prior to the incident, the reactive power output and voltage at PAREP PoC was around 26.5 MVAr and 1.037 per unit (p.u.), respectively.

The reactive power and voltage at the PoC of PAREP are shown in Figure 2 and Figure 3 respectively. Following this disturbance, small but gradually increasing oscillations are seen in the reactive power (Figure 2) and voltage (Figure 3).

These oscillations persisted for almost five hours until ElectraNet opened the CBs at Davenport to disconnect PAREP. During this time period, a maximum peak-to-peak magnitude oscillation of 247 MVAr in reactive power output and 0.077 p.u.in PoC voltage was recorded.

Figure 2 Reactive power at the PoC of PAREP

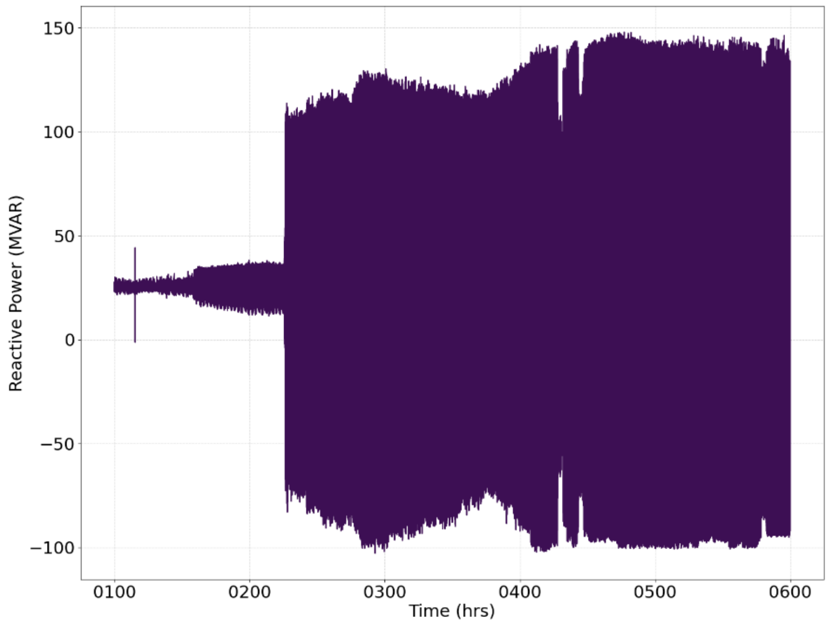
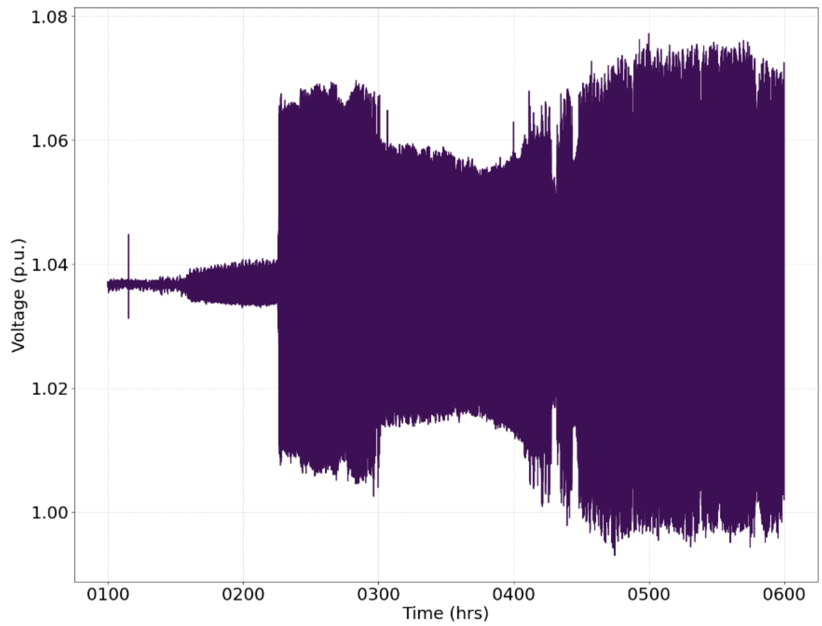


Figure 3 Voltage at the PoC of PAREP



2.5 Response of distributed energy resources (DER)

As the event predominately occurred at night, there was negligible DPV response to assess, but AEMO was able to assess residential battery behaviour. One battery manufacturer identified that 95% of its battery fleet disconnected at some point during the period of voltage and reactive power oscillations. The majority of systems were identified to disconnect multiple times, with at least five systems disconnecting and reconnecting more than 40 times during the event.

Based on discussions with the manufacturer, AEMO understands that the disconnection across the fleet was due to the use of an external device incorporated as part of the manufacturer's typical system configuration. Interrogation of event recordings from the devices indicates that the measurement of frequency by the external device may have been affected by the distortion of the voltage waveform caused by oscillations on the power system. This issue was not apparent from the event recordings obtained from the associated inverters that have been certified under AS/NZS 4777.2:2020. The affected frequency measurement resulted in the disconnection of sites (load and generation) by the external device.

AEMO has discussed potential solutions with the manufacturer to manage this risk, such as shifting the functionality from the external device to the battery's inverter until a new generation of product is available. Once it is available, the external device will be tested with the inverter to AS/NZS4777.2:2020 requirements. AEMO is seeking to clarify requirements within the Australian Standards relating to devices external to the inverter, but which can impact the overall system performance.

3 Power system security

AEMO is responsible for power system security in the NEM. This means AEMO is required to operate the power system in a secure operating state to the extent practicable and take all reasonable actions to return the power system to a secure state following a contingency event in accordance with the NER[11].

AEMO has analysed the impact of this incident on power system security and has concluded that:

- The voltage and reactive power oscillations did not impact power system frequency and the Frequency Operating Standard[12] was met in relation to this incident.
- At no point during this incident were transmission system voltages outside of relevant voltage limits (to confirm, the voltage at PAREP PoC oscillated between 0.992 p.u. and 1.077 p.u. during the incident).
- The current flows on all transmission lines remained within secure limits throughout the incident.
- All other plant forming part of or impacting on the power system was operated within secure limits throughout the incident.
- There was no widespread disruption to the power system. Disconnection of residential batteries of one specific manufacturer was reported, with several reports of strange power system effects such as flickering lights.
- As the incident occurred in the early hours of the morning when there was no solar irradiance, there was no notable response from DPV in response to this incident.
- Voltage and reactive power oscillations persisted for almost five hours with a maximum measured peak-to-peak voltage magnitude of 0.077 p.u. at PAREP PoC.
- SAPN has confirmed that the voltage fluctuation levels recorded on the system exceeded the "compatibility levels" outlined in Clause S5.1.5 (AS61000.3.7)[13] during the incident.

[11] Refer to AEMO's functions in section 49 of the National Electricity Law and the power system security principles in clause 4.2.6 of the NER.

[12] Frequency Operating Standard, effective 1 January 2020, available at https://www.aemc.gov.au/media/87484.

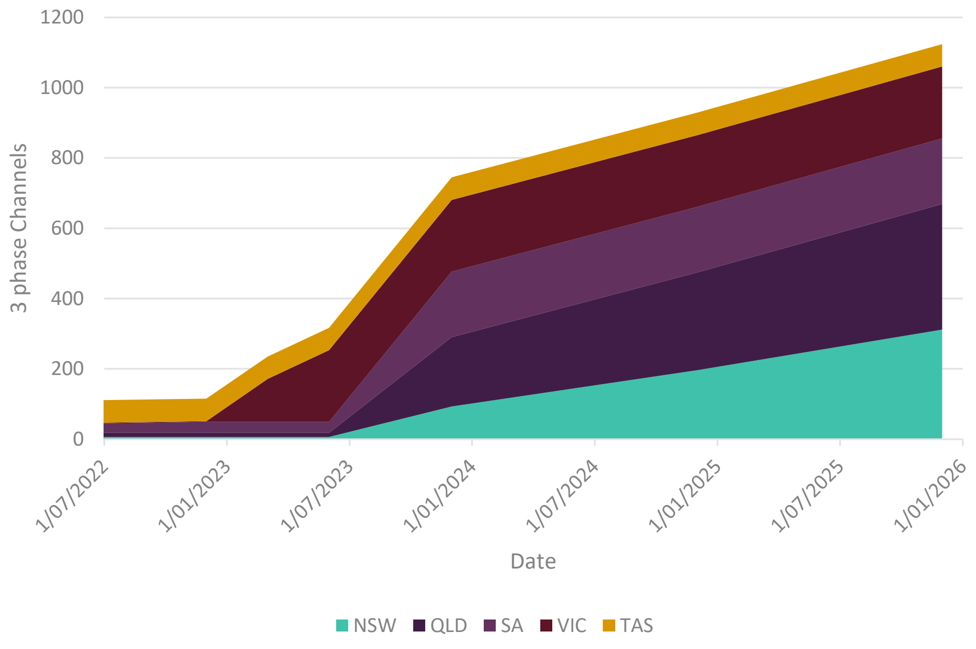
[13] Clause S5.1.5 states that the Network Service Providers must use reasonable endeavours to design and operate its transmission or distribution system to maintain voltage fluctuation levels for all supply points to customers supplied from their network below the "Compatibility Levels" defined in Table 1 of AS/NZS 61000.3.7:2001. SAPN confirmed that the voltage fluctuation levels did not meet "Compatibility Levels" set out in Table 1 of Australian Standard AS/NZS 61000.3.7:2001 during this incident.

It is likely these voltage and reactive power oscillations were not 'adequately damped' in line with the criteria set out in NER S5.1.8, although currently there is no defined operational limit which can be used to identify the level of background power system oscillation that is acceptable. It is realistic to expect some level of ongoing background system oscillation in power systems with significant amounts of operating grid-following inverter-based resources (IBR) and low system strength; however, given the magnitude of oscillations that occurred in this event, it is likely that they would exceed any threshold that is subsequently defined.

3.1 High-speed monitors and operational tools

During this incident, ElectraNet and AEMO were not aware of the voltage and reactive power oscillations until customers (including major industrial customers) and SAPN contacted ElectraNet. At present, AEMO has no automated reporting or alarming capabilities to monitor power system stability issues arising from control interactions between IBR. AEMO is working with TNSPs to improve high speed monitoring capabilities and implement tools to provide operators with visibility in real time. The project is being co-ordinated as part of AEMO's Operations Technology Roadmap[14] to uplift operational capability and help manage system security in the context of a power system increasingly dominated by IBR. Figure 4 presents the total number of high-speed monitor channels[15] planned for installation as part of this project and, when they are expected to become available.

Figure 4 Planned NEM HSM monitor installations



As part of the same project, there are plans to develop operational tools (including alarms and dashboards) to improve operator visibility of system oscillations. These tools will help operators identify the source of oscillations

[14] Please see https://aemo.com.au/-/media/files/initiatives/operations-technology-roadmap/executive-summary-report-for-the-otr.pdf?la=en for more details of the Operations Technology Roadmap.

[15] Many high-speed monitors include multiple measurement "channels" or measurements which AEMO will be able to review data from.

and take appropriate actions[16], which may include disconnection of unstable generator(s) as a last resort where automatic protection systems fail to disconnect the affected generator(s).

AEMO recommends that an acceptable oscillations limit is developed in conjunction with:

- suitable operational tools; and
- the installation of a suitable number of high-speed monitors,

to enable AEMO to monitor and effectively manage oscillations within operational timescales.

3.2 Reclassification

AEMO assessed whether to reclassify this incident as a credible contingency event[17]. This incident did not include any non-credible contingency events, therefore AEMO was not required to put any reclassifications in place.

4 Rectification

Following the incident, PAREP's control system code was corrected to ensure the inner control loop is changed to closed loop mode once the communication is restored, and it is safe to restart the wind turbine generators.

Post incident analysis identified that PAREP's performance standards required it to trip during this incident as it was in an unstable operating state. In consultation with AEMO, PAREP has since taken several rectification measures to provide the capability to trip the plant for unstable operation such as installing a protection relay that will detect electrical instability and, on detection of oscillation, raise and send Supervisory Control and Data Acquisition (SCADA) alarm to ElectraNet and AEMO control centres. It is also capable of disconnecting PAREP upon detection of oscillations, if needed.

5 Market information

AEMO is required by the NER and operating procedures to inform the market about certain incidents as they progress[18]. AEMO was not required to and did not issue any market notices during the course of this incident.

6 Conclusions

AEMO has assessed this incident in accordance with clause 4.8.15(b) of the NER. In particular, AEMO has assessed the adequacy of the provision and response of facilities or services, and the appropriateness of actions taken to restore or maintain power system security.

[16] Multiple monitors need to be available within a network area to allow operational tools and operators to locate the approximate source of any oscillations and identify a suitable response.

[17] AEMO is required to assess whether or not to reclassify a non-credible contingency event as a credible contingency event – NER clause 4.2.3A(c) – and to report how the reclassification criteria were applied – NER clause 4.8.15(ca).

[18] AEMO generally informs the market about operating incidents as they progress by issuing Market Notices – see https://www.aemo.com.au/Market-Notices.

AEMO has concluded that:

1. The root cause of reactive power oscillations was associated with human error, whereby incorrect control system code was applied at PAREP following a communications fail-safe test at 2000 hrs on 22 June 2022 (approximately five hours prior to the event).
2. At no point during this incident were transmission system voltages outside of relevant voltage limits.
3. Given ElectraNet's action to disconnect PAREP, no action was required by AEMO to restore or maintain power system security. The voltage and reactive power oscillations did not impact power system frequency and the Frequency Operating Standard was met in relation to this incident.
4. This incident did not include any non-credible contingency events, therefore AEMO correctly identified that no reclassifications were required.
5. As this incident occurred at night, the response of DPV systems was negligible, but AEMO was able to assess residential battery behaviour. One battery manufacturer identified that an external device, which is part of the manufacturer's typical battery system configuration, caused the disconnection of 95% of its residential battery fleet. The devices' event recordings indicate that the measurement of frequency by the external device may have been affected by the distortion of the voltage waveform caused by oscillations on the power system. AEMO has discussed potential solutions with the manufacturer, such as shifting the functionality from the external device to the battery's inverter, until a new generation of product is available.

7 Recommendations

As a result of this incident review, AEMO has identified several issues to address with the intention of mitigating operational risks in the power system. As NEM progressively transitions to higher levels of IBR and DER, it is increasingly critical to evaluate such risks.

Based on the findings, AEMO makes the following recommendations:

1. Generator operators have procedures in place to ensure that, when generator or power system instability is identified, appropriate actions can be taken within a reasonable timeframe. These actions could include advising AEMO and NSP control rooms of the instability, investigation of the instability to determine if the generator is contributing, and, if required, disconnection of the generating facility.
2. To allow generators, NSPs and AEMO to more effectively identify and respond to power system instabilities during commissioning and in the course of normal operations - AEMO recommends that all NSPs require new connections install PMU's at / adjacent to the connection point. PMUs should have the capability for high speed monitoring and live streaming of data to proponent, NSP and AEMO control rooms[19]. It is expected that NSPs would consider the capacity, characteristics of the plant and characteristics of the network at the connection location in determining whether this requirement should apply for a given connection.
3. AEMO is currently consulting with industry on guidelines for how generators can best comply with NER S5.2.5.10 (protection to trip for unstable operation) for asynchronous generators[20]. AEMO will consider a strategy for engaging further with existing proponents once these guidelines are updated.

[19] AEMO notes that some NSPs require already new generator connections include a PMU at the generator connection point with live data streaming to the NSP control room.

[20] For more information, see https://aemo.com.au/consultations/current-and-closed-consultations/ner-s52510-guideline-consultation.

4. As part of the access standards review[21], for new connections, AEMO is currently engaging with industry on the suitability of the requirements of NER S5.2.5.10 (protection to trip plant for unstable operation), with a focus on asynchronous generators. As part of this engagement, AEMO will consider amendments to the access standards for generators to:
   4.1. Monitor for instability and alert generator operators, the NSP and AEMO.
   4.2. Determine their contribution to system instability.
   4.3. Trip or ramp down under critical system conditions where the system is unstable and/or where a generator identifies itself as a high contributor to the identified system instability.
5. Consistent with recommendations relating to the West Murray Zone power system oscillations event on 16 November 2021, AEMO recommends that an acceptable oscillations limit is developed in conjunction with suitable operational tools and installation of adequate high-speed monitors to support control room operators in managing future oscillation events on the power system. This will enable operators to monitor and effectively manage oscillations within operational timeframes, and involves the following recommended steps:
   5.1. AEMO, in conjunction with TNSPs, to improve high speed monitoring capabilities and implement visualisation tools providing system operators with real-time information needed to respond if automatic protection systems fail to disconnect the affected generation. For more information on this recommendation, see Section 3.1 of this report.
   5.2. The PSSWG to define a level of power system oscillations which may be considered acceptable for secure power system operation in the operational timeframe, which may be used to support TNSPs when providing operational limits advice.
   5.3. All TNSPs to provide AEMO with updated limit advice (where required) consistent with the acceptable level of oscillations, and identify operational actions that AEMO can take if available monitoring indicates power system oscillations exceeding the acceptable level.
6. Through this event, AEMO identified areas within the current Australian Standards (AS/NZS4777.2:2020) that require clarification related to the testing, performance, and use of external devices that could affect the performance of Distributed PV and household battery system inverters. AEMO is currently pursuing activities to clarify requirements within the Australian Standards (AS/NZS4777.2:2020) related to devices external to household inverters which can impact overall system performance.
7. Noting recent issues that have occurred during generator commissioning, AEMO recommends that generators review commissioning procedures to ensure controls are in place, including post-test checks and continuous monitoring during the commissioning process. AEMO plans to communicate this as part of generator commissioning requirements review. In addition, when reviewing new test plans, AEMO will consider the findings of this report and (where appropriate) request that test plans include additional controls to mitigate potential risks that may arise during commissioning.
8. AEMO is currently reviewing the generator commissioning requirements and will consider the findings and recommendations of this incident as part of that review[22].

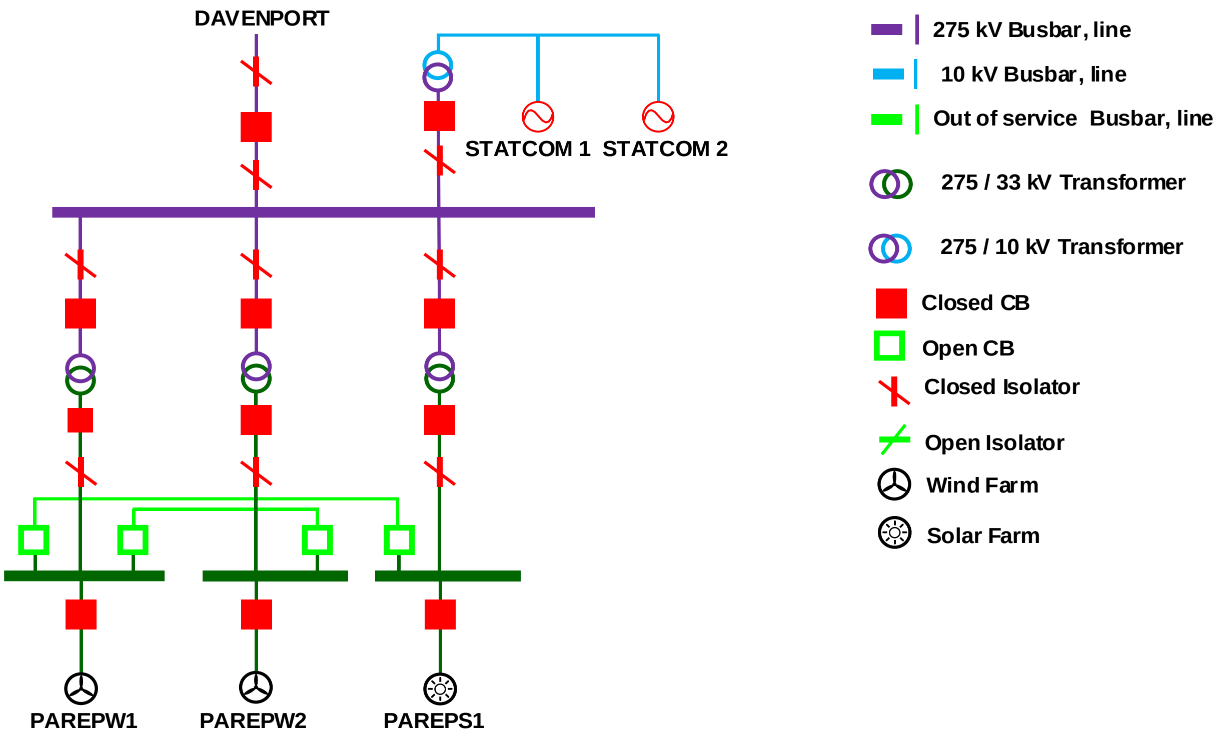
[21] For more information, see https://aemo.com.au/consultations/current-and-closed-consultations/aemo-review-of-technical-requirements-for-connection.

[22] See https://aemo.com.au/-/media/files/electricity/nem/network_connections/transmission-and-distribution/generating-system-test-template-for-non-synchronous-generation.docx?la=en and https://aemo.com.au/-/media/files/electricity/nem/network_connections/transmission-and-distribution/generating-system-test-plan-template-for-conventional-synchronous-machines.pdf?la=en

9. In the 2023 General Power System Risk Review, AEMO plans to consider the risks of a similar event occurring during a daytime period where a large amount of DPV is disconnected due to power system oscillations.

A1. System diagram

Figure 5 PAREP connection arrangement



A2. PAREP fail-safe strategy

PAREP communication fail-safe logic monitors the health of the power meters. In the event of a primary and fallback power meter failure, the Hybrid Power Park Controller (HPPC) shall operate as outlined in Table 2. In this event, due to the error that was introduced in to the PAREP's control system code, HPPC did not revert back to the voltage droop control loop as it reverts to standard operation.

Table 2 HPPC and power meter communication fail-safe mechanism and tested settings

Communication failure sequence	Requirement	Tested communication fail-safe mechanism	Verified/Tested settings
Failure of primary Bachman meter	Backup meter	The HPPC will revert to the backup Bachmann meter.	N/A
Failure of primary & backup Bachmann meters	Detection time setting	HPPC is able to detect communication loss.	< 500 milliseconds
	Alarm	Alarm was initiated in Supervisory Control and Data Acquisition-Power Park Controller log for PoC meter communication loss.	Immediate on detection
	Time out time setting	The HPPC will timeout after 30 seconds if communication loss sustains.	30 seconds
	Time out HPPC set points settings	The HPPC will change from the Voltage Droop Control Loop "V" to the Reactive Power Control Loop "Q". The PPC will maintain its last received P and Q HPPC setpoints during this 30 sec period.	Pre-fail P and Q setpoints
Non-sustained comms failures **(< 30 seconds)**	Standard operation for non-sustained fail	HPPC will revert to standard operation and will revert to the Voltage Droop Control Loop "V".	Refreshed HPPC set points.
Sustained comms failures (>30 seconds) or two comms failures within 60 minutes	Ramp down to zero	HPPC will ramp down all wind turbine generators within 5min until 0 MW/0 MVAr output is achieved at wind turbine generators.	< 5 minutes
Recovery of comms	Recovery after manual acknowledgment	Upon comms recovery, the wind turbine generators will not automatically ramp up after recovery until the following steps are performed in sequence: 1. The operator acknowledges the alarms. 2. The operator requests approval from AEMO/TNSP, and then manually restart the wind turbine generators.	Ramp-up after manual acknowledgment

A3. Participants who provided data

AEMO would like to thank the following participants for providing data to support review of this event.

Table 3 Participants who provided data

Participant	Station name
AGL Energy	Hallett 4 North Brown Hill Wind Farm
	Hallett 5 The Bluff Wind Farm
	Hallett Stage 1 Brown Hill
	Hallett Stage 2 Hallett Hill
ElectraNet	Belalie
	Corraberra Hill
	Cultana
	Davenport synchronous condensers
	Mount Lock
Energy Australia	Hallet Gas turbines
Iberdrola Australia	PAREP
Neoen Australia	Hornsdale Power Reserve
	Hornsdale Wind Farm stage 1
	Hornsdale Wind Farm stage 2
	Hornsdale Wind Farm stage 3
Nexif Energy	Lincoln Gap Wind Farm
Origin Energy	Bungala Solar Farm
Tilt Renewables	Snowtown Wind Farm