AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Final Report – Total loss of AEMO SCADA systems on 24 January 2021

September 2021

Reviewable operating incident report under the National Electricity Rules

INCIDENT CLASSIFICATIONS

Classification	Detail
Time and date of Incident	1344 hrs on 24 January 2021
Region of incident	NEM-wide
Affected regions	NEM-wide
Event type	SCADA outage
Generation impact	Nil
Customer load impact	Nil
Associated reports	Preliminary Report – Total loss of SCADA systems on 24 January 2021[1]

ABBREVIATIONS

Abbreviation	Term
5MDF	Five-Minute Demand Forecaster
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AEST	Australian Eastern Standard Time
AGC	Automatic Generation Control
ASEFS	Australian Solar Energy Forecasting System
AWEFS	Australian Wind Energy Forecasting System
EMMS	Electricity Market Management System
EMS	Energy Management System
NEM	National Electricity Market
NER	National Electricity Rules
RRP	Regional Reference Price
SCADA	Supervisory Control and Data Acquisition
TNSP	Transmission Network Service Provider

[1] See https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2021/preliminary-report-total-loss-of-nem-scada-data.pdf?la=en.

Important notice

PURPOSE

AEMO has prepared this final operating incident 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. This final operating incident report supersedes the previously published preliminary incident report[2].

DISCLAIMER

To inform its review and the findings expressed in this report, AEMO has been provided with data by Registered Participants as to the performance of some power system equipment during the incident described. In addition, AEMO has collated available information from its own systems.

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.

AEMO has made every reasonable effort to ensure the quality of the information in this report but cannot guarantee its accuracy or completeness. Accordingly, to the maximum extent permitted by law, AEMO and its officers, employees and consultants involved in the preparation of this report:

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CONTACT

If you have any questions or comments in relation to this report, please contact AEMO at system.incident@aemo.com.au.

The NEM operates on Australian Eastern Standard Time (AEST). All times in this report are AEST.

[2] At https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2021/preliminary-report-total-loss-of-nem-scada-data.pdf?la=en.

Contents

1. Overview

This is AEMO's final report in relation to an internal AEMO Supervisory Control and Data Acquisition (SCADA) service failure that occurred on 24 January 2021 impacting all National Electricity Market (NEM) regions. This incident resulted in the loss of AEMO's SCADA system for around 55 minutes.

The SCADA system is used to monitor and operate the NEM; SCADA feeds into both the Energy Management Systems (EMS) used to monitor the power system and the Electricity Market Management Systems (EMMS) used to dispatch generating units.

The review of this incident is undertaken consistent with clause 6(f) of the Reliability Panel guidelines[3], given the significance of the event.

This final report is prepared in accordance with clause 4.8.15(c) of the National Electricity Rules (NER) and supersedes AEMO's preliminary report published on 16 February 2021 (Preliminary Report)[4]. It provides further analysis of the following issues:

- The cause of the loss of AEMO SCADA and the immediate actions taken to resolve the issue.
- The impact on the power system and whether the power system remained in a secure operating state.
- The impact of primary frequency response on power system frequency performance.
- The impact on the market, including a review of pricing outcomes, the impact on the demand forecast process, the impact on constraint equations, and the performance of the 5-minute forecasts for renewable generation.
- The provision of information to the market.
- The application of procedures associated with market suspension.
- Other related incidents.
- Recommended actions.

This report also provides some additional information related to other IT events, including a loss of Victorian SCADA and a SCADA communications issue that occurred on 16 February 2021.

AEMO's conclusions are summarised in Table 1. Key findings are discussed in further detail in the report body.

Table 1 Summary of conclusions for 24 January 2021 loss of NEM SCADA event

Finding	Actions recommended or underway
The power system remained in a secure operating state throughout this incident.	No action required.
The Frequency Operating Standard (FOS) was met for this incident.	No action required.
Primary Frequency Response (PFR) enabled generation responded correctly throughout this event to maintain system frequency with the FOS, despite periods where Regulation Frequency Control Ancillary Services (FCAS) was not enabled in the system. The aggregate PFR response peaked at a maximum of around 1,157 megawatts (MW) below dispatch targets when system frequency was approaching 50.15 hertz (Hz).	No action required.

[3] See https://www.aemc.gov.au/sites/default/files/2018-02/Final-revised-guidelines.pdf.

[4] See https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2021/preliminary-report-total-loss-of-nem-scada-data.pdf?la=en.

Finding	Actions recommended or underway
Heartbeat delays were detected at 1347 hrs and 1349 hrs shortly after the initial event. These heartbeat delays could have theoretically warned the AEMO control room or IT team that there was an issue, but they were not alarmed.	AEMO to implement real-time monitoring and alerting of the SCADA heartbeat delays. This will allow for proactive remediation of issues prior to broader system degradation. Targeted for implementation Q4 2021.
Loss of SCADA occurred approximately 81 minutes after the first heartbeat delay. The IT team was notified after the SCADA failed at 1546 hrs.	AEMO to implement real-time monitoring and alerting of the SCADA heartbeat delays. This will allow for proactive remediation of issues prior to broader system degradation. Targeted for implementation Q4 2021. AEMO to review and update its internal major incident management and escalation processes and procedures and ensure they are used expediently during an incident. This review in in progress and is due to be completed by 31 October 2021. AEMO to continue training and refresher training for appropriate staff on the above procedures.
In response to the AEMO SCADA loss at 1546 hrs, AEMO communicated directly with generators and network service providers (NSPs) to manage the event, with a Market Notice issued 47 minutes later.	AEMO plans to review whether broader communication to the market relating to IT incidents could be issued in a more timely manner. This review is in progress and due for completion by 30 September 2021
The existing process of replication and replay across servers allowed the error condition to be propagated into the entire environment.	AEMO to work with support vendor GE to review the best practice for maintaining high availability in the SCADA system. Review targeted for completion Q4 2021.
Due to a software bug, the AEMO SCADA system was unavailable for around 55 minutes.	On 28 January 2021 a software patch to remove the software bug was applied to AEMO's Queensland control centre SCADA system. The same software patch was applied to AEMO's New South Wales control centre SCADA system on 29 January 2021.

2. Pre-event conditions

Prior to the loss of SCADA, the power system was in a secure operating state, no reserve conditions existed, and no abnormal risks to the power system had been identified.

3. Incident overview and cause of failure

At 1344 hrs on 24 January 2021, an AEMO operator performed a normal action[5] in response to a datapoint alarm on the active SCADA session in the New South Wales control room. The operator repeated this action around 25 seconds later, in accordance with normal practice.

This repeated action in a short timeframe unexpectedly prevented the alarm process restarting.

[5] A facility is available in the SCADA system to ignore/silence repeating alarms which do not require operator action.

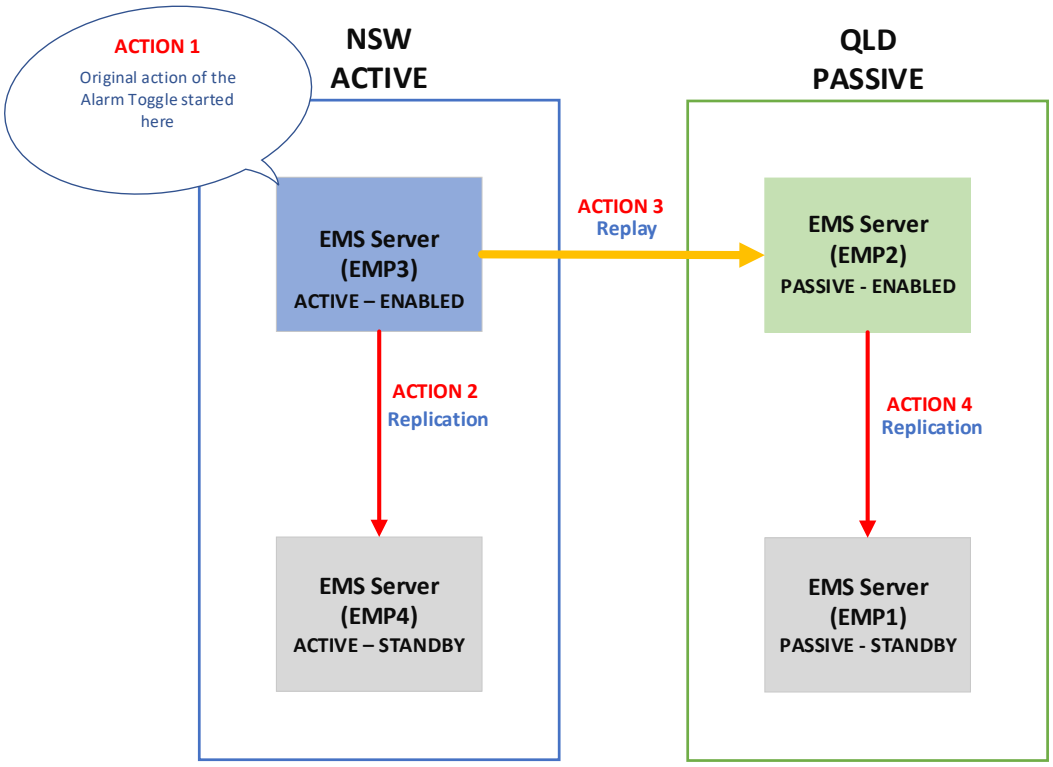
A system bug then occurred on the standby server, that started a chain of events eventually causing the failure of the entire NEM SCADA session.

A high-level overview of the chain of events is outlined below (refer also to Figure 1 and Table 2):

- The normal inter-site replay system copied the operator's actions from the ENABLED server (in New South Wales) to the ENABLED server (in Queensland). This process is designed to ensure the databases at both sites remain consistent to provide full system redundancy in case of a site failure.
- The normal intra-site replication system tried to copy the database change from the ENABLED server (at both sites) to the STANDBY server at each site, but the copy was corrupted. This copy process is designed to ensure full system redundancy within each site.
- The alarm process on the STANDBY server (at both sites) crashed because of the corrupt copy of the first operator action, and then restarted.
- The alarm process on the ENABLED server (at both sites) crashed again due to the corrupt copy of the second operator action, but this time did not restart.
- Event monitoring identified the condition but control room operators were not alerted to the issue as it had no associated alarm.
- The crashed alarm processors on both the STANDBY servers then negatively impacted the intra-site replication systems at both sites.
- The problems with the intra-site replication systems caused progressive degradation of both ENABLED servers until full failure occurred at 1546 hrs.

This service failure resulted in NEM control room operators being unable to see or operate the SCADA session from either of the AEMO control rooms.

Figure 1 **SCADA overview**



As per the relevant AEMO operating procedures, transmission network service providers (TNSPs) were informed of the failures and requested to monitor the power system and advise AEMO of any issues.

Generators were also requested to go off Automatic Generation Control (AGC) and follow the targets provided by the market systems.

At 1645 hrs on 24 January 2021, restart of a Queensland server enabled the control room to restore a non-redundant SCADA service. Full redundancy (post the New South Wales server restart) was restored by 1656 hrs on 24 January 2021.

Table 2 Loss of SCADA incident summary

Date/time	Event
20 Jan 2021	
	AEMO reported a potential software bug to the support vendor (GE). GE responded on 21 January 2021 with patch advice for this known error, and recommended that this patch be applied. AEMO intended to apply the patch in the next patching cycle expected in March 2021 because, at the time, it was not known how the error condition was activated or that the standby server error condition would impact the enabled server.
24 Jan 2021	
1344	AEMO performed two standard toggle actions to silence a datapoint alarm on the EMS. The Replay system copied the first change from the enabled server in New South Wales (the active site) to the enabled server in Queensland. The system tried to copy the change from the enabled server in Queensland (EMP2) to the standby server in Queensland (EMP1) but the copy was corrupted. The alarm processor on the standby host in Queensland crashed and was restarted. The system tried to copy the change from the enabled server in New South Wales (EMP3) to the standby server in New South Wales (EMP4) but the copy was corrupted. The alarm processor on the standby host in New South Wales crashed and was restarted.
1345	The alarm processor on the active standby host at the New South Wales site crashed again due to the copying of the second toggle command but did not restart and stayed inactive.
1345	The alarm processor on the passive enabled host in Queensland crashed again due to copying of the second toggle command but did not restart and stayed inactive.
1347	A 15.7 second delay in SCADA data on the enabled host in Queensland was detected but was not alarmed. The systems were repeatedly trying to copy to the alarm systems on the standby servers, which created queues for copying data in particular SCADA areas. When the queues built up, this resulted in intermittent shut down of SCADA applications on the enabled servers at both sites. This in turn led to communication links periodically dropping out.
1349	AEMO's post incident investigation identified that a 3.2 second delay in SCADA data on the enabled host in New South Wales was detected in the system but AEMO control room staff were not alerted as this delay was not alarmed.
1408	First system alarm was received at the AEMO control room indicating intermittent loss of data path between sites.

Date/time	Event
1411 onwards	SCADA data flow to EMS was interrupted periodically for short periods, however such intermittent issues are not specifically monitored by the AEMO control room. The magnitude of the issue only became evident to the control room shortly before 1517 hrs when large-scale failures of SCADA data occurred.
1517	Following observations of intermittent frequency failure (NEM EMS Market display and frequency traces and EMS time "pauses"), AEMO on-call personnel were contacted by the NEM control room to investigate.
1517	Snowy Hydro contacted AEMO Support Hub advising of delays to 4-second control signal targets occurring from around 1356 hrs.
1530	Snowy Hydro provided further detail to AEMO Support Hub stating that problems with targets commenced about 1356 and were getting worse.
1546	Indications had been received in AEMO Control Rooms that all NEM SCADA had become suspect, failed, or was very slow to update. Transferring EMS from New South Wales to the passive site in Queensland was not possible, because the passive site was also experiencing the same SCADA issues. AEMO began requesting that AGC generating units in all regions turn off AGC and follow NEM targets via market systems manually. Generators were requested to advise AEMO if they were unable to follow NEM targets or if any significant changes occurred with generating units. AEMO also requested Generators advise any abnormal frequency indications. TNSPs in all regions were requested to monitor the power system for any significant or abnormal changes and report immediately to AEMO any material changes to frequency, line and interconnector loading, voltage levels and unplanned outages. TNSPs were also requested to perform voltage control under consultation with AEMO.
1633	AEMO issued Market notice 82330 (AEMO SCADA Failure NEM 24/01/2021).
1641	Process manager stopped on standby EMS server in Queensland, restoring service and allowing SCADA data to update normally. From 1641 hrs to 1653 hrs, AEMO requested all Generators to turn back onto AGC.
1643	Control site transfer was completed, making Queensland active and New South Wales passive.
1645	All AEMO SCADA returned to normal on the Queensland EMS session.
1656	Process manager stopped on standby EMS server in New South Wales, fully restoring service and allowing SCADA data to update normally.
1708	AEMO issued Market notice 82340 (AEMO SCADA Failure NEM 24/01/2021).
1955	Root cause had been identified and system stability restored, with additional monitoring in place.

Date/time	Event
29 Jan	Software patch was successfully applied to Queensland Production System.
1 Feb	Software patch was successfully applied to New South Wales Production System.
5 Feb	Software patch was successfully applied into WA EMS Production sites.

Note: because Western Australia is a separate system, the WA Electricity Market (WEM) EMS was not affected.

3.1 Incident observations

Post incident investigation confirmed that the event that led to the loss of AEMO SCADA occurred at 1344 hrs on 24 January 2021. Three and five minutes after the initial event there were two SCADA heartbeat delays that indicated a problem, however, these heartbeat delays did not alarm and therefore AEMO was unaware of the issue. Full SCADA failure then occurred 29 minutes later at 1546 hrs.

The process of replication and replay across servers is used to keep the data at both the active and passive sites enabled and standby servers up-to-date and synchronised, allowing for high availability services. While this maintains high availability, in this incident it allowed an error condition to be propagated into the entire environment.

4. Power system security

Although widespread loss of SCADA is an uncommon event, AEMO has procedures to manage the situation.

In line with AEMO's procedures throughout this incident, power system parameters including interconnector transfers, and frequency and voltage levels were monitored via consultation with transmission network service providers (TNSPs)[6] to establish if any significant errors existed between dispatch and actual power system conditions. In addition, each TNSP was asked to monitor power system security in its respective region and report any issues to AEMO for the period that SCADA remained unavailable.

At 1645 hrs on 24 January 2021, South Australian TNSP ElectraNet informed AEMO that a bushfire in South Australia had tripped multiple transmission lines around Cherry Gardens substation (full details of this incident are covered under a separate report[7]). As AEMO's SCADA system was becoming functional around the same time, AEMO was able to respond appropriately to this incident and maintain power system security.

AEMO has concluded that the power system remained in secure operating state for the duration of this incident.

5. System frequency

[6] The TNSPs' SCADA systems were operational, but peripheral SCADA they receive from AEMO was impacted.

[7] At https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2021/trip-of-multiple-cherry-gardens.pdf?la=en.

As a result of this incident, AEMO lost operational visibility of the SCADA and market systems which dispatch generation and provide centralised frequency control. In response to the loss of SCADA, AEMO asked generators to come off AGC and follow market targets manually. With generators manually following targets, their AGCs were unable to receive and respond to control signals for the purpose of providing Regulation Frequency Control Ancillary Services (FCAS). Frequency was controlled during this event through dispatching generation based on forecasts of demand and by a number of generators providing primary frequency response (PFR). In addition, the AEMO control room was able to maintain visibility of the power system frequency through back-up systems.

During the period SCADA was unavailable, the system frequency reached a maximum of around 50.16 hertz (Hz) and remained above 50.15 Hz for around four seconds. The system frequency also reached a minimum of 49.9 Hz during this incident. The Frequency Operating Standard (FOS) was maintained for this event[8].

5.1 Primary frequency response during the incident

The initial stage of progressive PFR implementation at large generating units commenced in September 2020, in response to the Mandatory PFR rule made by the Australian energy Market Commission (AEMC) in March 2020[9]. Generators required to provide PFR should respond to locally detected changes in frequency by adjusting their output to resist changes in system frequency. The magnitude of this response should increase as frequency drifts further from 50 Hz and generators should be able to respond to frequency changes within 10 seconds. By January 2021, approximately 29.1 gigawatts (GW) of generation capacity across the NEM had either fully or partially implemented PFR settings, or were already providing PFR that met the PFR parameters.

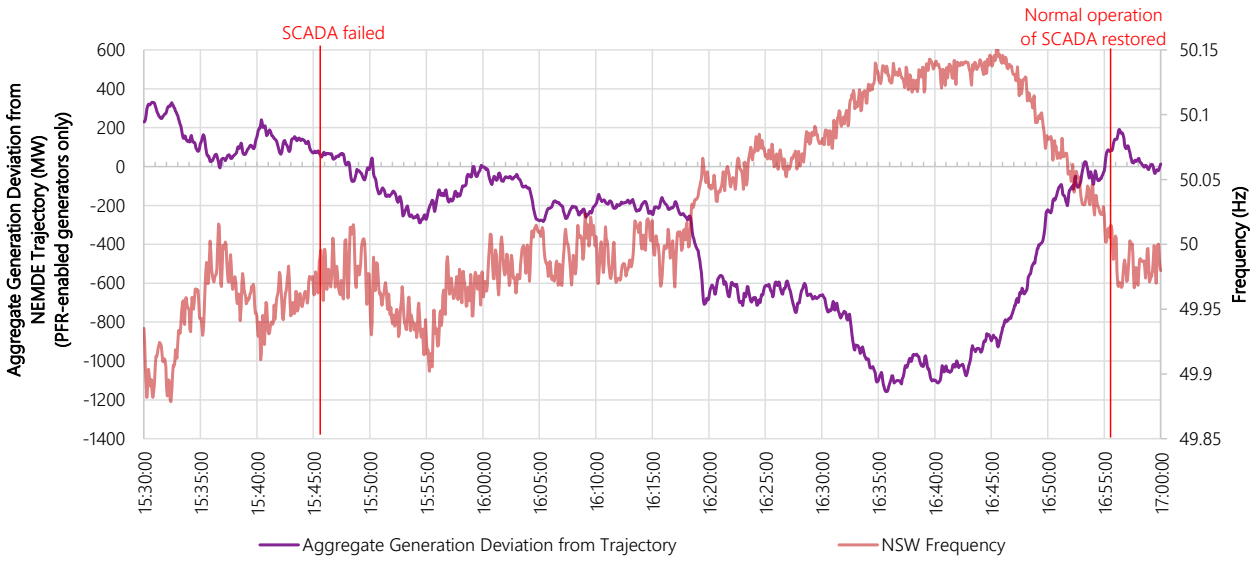
The purple trace in Figure 2 below shows (in aggregate) how the generating units providing PFR moved from their dispatch targets to help maintain system frequency.

It shows that these generators correctly ramped down active power output from 1620 hrs to 1635 hrs as system frequency increased. Aggregate PFR response peaked at a maximum of around 1,157 megawatts (MW) below dispatch targets when system frequency was approaching 50.15 Hz. PFR response then correctly decreased (active power increased) from 1645 hrs to 1655 hrs (moving closer to dispatch targets) as system frequency moved towards 50 Hz. These responses from PFR generators had the effect of maintaining system frequency within the FOS during this incident.

[8] See the Frequency Operating Standard (FOS) at https://www.aemc.gov.au/sites/default/files/2020-01/Frequency%20operating%20standard%20-%20effective%201%20January%202020%20-%20TYPO%20corrected%2019DEC2019.PDF.

[9] National Electricity Amendment (Mandatory primary frequency response) Rule 2020 No. 5, at https://www.aemc.gov.au/rule-changes/mandatory-primary-frequency-response.

Figure 2 Loss of SCADA incident primary frequency response



6. Market impact

6.1 Market system response

The Electricity Market Management System (EMMS) relies on accurate SCADA information to calculate the dispatch level of generators as well as prices for energy and FCAS. The central dispatch process including NEMDE operated throughout the period that SCADA was unavailable.

AEMO's strategy was to continue to dispatch generating units via dispatch targets from the National Electricity Market Dispatch Engine (NEMDE). In the event of a loss of SCADA, generally NEMDE will use:

- Targets from the previous dispatch interval as the initial active power setpoint for the next interval for scheduled and semi-scheduled generating units.
- The last good value received from the SCADA system for up to 72 hours for unscheduled data.

A review of data from major generating units indicates system response was overall consistent with the two actions above.

6.2 Market outcomes

The notable pricing and dispatch issues identified during the incident were:

- A price spike in Queensland to $2,173 and $15,000 per megawatt hour (MWh) for Dispatch Intervals (DIs) ending 1635 hrs and 1640 hrs respectively.
- Significant rises in prices for lower and raise Regulation FCAS services in the period 1615 hrs to 1645 hrs.

Aside from these notable outcomes, explored in more detail below, prices across the NEM were elevated but unremarkable over the period of the loss of SCADA (averaging around $300/MWh).

Price spike in the energy market for the Queensland region

The price spike in the Queensland energy price can largely be attributed to the action of two network constraints in Central Queensland that were likely affected by the loss of SCADA:

- Q>>NIL_CLWU_RGLC, a system normal thermal constraint that aims to prevent an overload of the Raglan to Larcom Creek 275 kilovolt (kV) line following the trip of the Calvale to Wurdong 275 kV line – coincident with the loss of SCADA, this constraint bound briefly at DI ending 1555 hrs before binding for every DI between 1610 hrs and 1645 hrs, and violating at DI ending 1640 hrs. This constraint uses a dynamic/telemetered rating; it was not updated during the SCADA outage and defaulted to the last good value.
- Q>>NIL_BCCP_RGLC, a system normal thermal constraint that aims to prevent an overload of the Raglan to Larcom Creek 275 kV line following the trip of the Bouldercombe to Calliope River 275 kV line – this constraint violated at DI ending 1640 hrs. This constraint uses a dynamic/telemetered rating; it was not updated during the SCADA outage and defaulted to the last good value.

These two constraints constrained down the output of several generators in Queensland, decreasing available supply and hence causing a sharp rise in prices. The action of the above constraints was impacted by the loss of SCADA, and the constraints ceased binding/violating at 1645 hrs on 24 January 2021, which is the time at which AEMO SCADA was returned to normal at the Queensland site.

The price spikes which occurred at the start of the trading interval were followed by three DIs at the market floor price to finish the trading interval, as a number of generators rebid capacity from higher priced bands to the market floor price seeking to maximise their energy dispatched for the trading interval. The Queensland energy price for the trading interval ending 1700 hrs was $2,387.21 per MWh.

Table 3 Queensland Regional Reference Price (RRP)

DI ending (hrs)	Queensland RRP ($/MWh)
24/01/2021 16:35:00	2,173.06
24/01/2021 16:40:00	15,000.00
24/01/2021 16:45:00	150.21
24/01/2021 16:50:00	-999.99
24/01/2021 16:55:00	-999.99
24/01/2021 17:00:00	-999.99

Regulation FCAS price rises across the NEM

Regulation FCAS services are managed by AEMO's AGC system, which sends signals to generating units every four seconds to adjust their output. Generator outputs are adjusted to maintain system frequency and time error within the FOS, and to ramp units able to be operated remotely to their dispatch target.

The loss of SCADA affected AEMO's AGC system. No dispatch instructions were issued for Regulation Raise and Lower FCAS in DIs ending 1550 hrs, and 1620 hrs to 1645 hrs. In these intervals, all units were identified as being off AGC and consequently unavailable for Regulation FCAS, so no instructions were issued[10]. In DIs ending 1550 to 1615 hrs, some units were identified as available for AGC and were dispatched for Regulation FCAS. However, this data is also believed to be suspect.

With all the generating units unavailable for Regulation FCAS, constraints[11] that related to minimum requirements for Regulation Raise and Lower services violated and prices in these markets spiked, peaking at $7,892/MWh for the Raise service and $7,469/MWh for the Lower service.

[10] With the exception of two Poatina units that had their AGC status set to ON.

[11] F_I+LREG_0210, F_I+RREG_0220, F_MAIN++RREG_0220, F_MAIN+NIL_DYN_RREG, F_TASCAP_LREG_0210, F_TASCAP_RREG_0220.

Table 4 AGC status and Regulation FCAS prices

DI ending (hrs)	15:50	15:55	16:00	16:05	16:10	16:15	16:20	16:25	16:30	16:35	16:40	16:45	16:50
Number of units with 'ON' AGC status	0	58	58	58	37	37	2	2*	2*	2*	10	17	62
Raise Reg price Mainland ($/MWh)	279.25	38.72	33.97	32.36	112.95	286.96	2,652.20	2,646.36	2,678.81	2,659.43	7,891.78	866.00	32.00
Lower Reg price Mainland ($/MWh)	1.03	16.55	10.88	14.73	21.00	21.00	2,376.44	2,374.82	2,402.62	2,383.95	7,468.72	883.96	1.03

AEMO has confirmed that scheduling errors occurred in the DIs between 1550 hrs and 1645 hrs on 24 January 2021[12].

6.3 Impact on Demand Forecasting System

AEMO's Demand Forecasting System (DFS) automatically generates demand forecasts every half-hour.

The forecast models that form part of the demand forecasting of the DFS use many key inputs:

1. Historical actual metered loads.
2. Real-time actual metered loads (SCADA data from immediately preceding intervals).
3. Historical and forecast weather data (temperature and humidity).
4. Significant non-scheduled wind generation forecasts (from Australian Wind Energy Forecasting System (AWEFS)).
5. Significant non-scheduled solar generation forecasts (from Australian Solar Energy Forecasting System (ASEFS)).
6. Small-scale (rooftop) solar generation forecasts (from ASEFS2).
7. Type of day (weekday/weekend), school holidays, public holidays and daylight savings information.
8. Reliability and Emergency Reserve Trader (RERT) schedule.

During the period of loss of SCADA, real-time actual metered load data (from SCADA) was unavailable. When this occurs, the DFS continues to produce forecasts but uses generation 5-minute dispatch targets to estimate the demand in each DI. While operating in this way, the DFS can continue to produce reasonably accurate forecasts for a limited period of time. The Pre-Dispatch (PD) Projected Assessment of System Adequacy (PASA) and Short Term (ST) PASA forecasts for 1630 hrs and 1700 hrs were completed using the DFS in this operating state and the overall impact on these forecasts was minimal. By around 1640 hrs, SCADA was beginning to update and the DFS returned to using the real-time actual metered data from SCADA for forecasts.

[12] For more information, see the declaration spreadsheet at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-events-and-reports/scheduling-error-reports.

6.4 Impact on Five-Minute Demand Forecaster

The Five-Minute Demand Forecaster (5MDF) inputs demand forecast values into NEMDE. During the AEMO SCADA outage, the 5MDF stopped updating and produced suspect demand forecasts, with the central dispatch process defaulting to a back-up process. The back-up process used historic demand values and the initial region supply from the previous dispatch interval to forecast demand for use in NEMDE.

This appeared to have a moderate impact on the accuracy of the demand being used by NEMDE, however the impact is difficult to quantify due to the lack of actual SCADA demand data to compare against. Moderate forecast deviations from the typical afternoon demand ramp were observed for South Australia, Tasmania, and Victoria.

6.5 Impact on renewable forecasting process

There are three major types of renewable forecasting processes operating in the NEM; each was impacted differently by the loss of AEMO SCADA:

- Dispatch self-forecasting – renewable generators who self-forecast use their own systems and models to provide dispatch self-forecasts of their semi-scheduled generating units for use in NEMDE. Generator forecasts produced by this method were unaffected by the loss of SCADA.
- ASEFS and AWEFS dispatch – renewable generators in this category use the ASEFS or AWEFS forecasts of their semi-scheduled generating units for use in NEMDE. These tools use inputs from SCADA and numerical weather prediction data to forecast renewable generator outputs. During the loss of SCADA these systems received intermittent bad quality SCADA inputs, leading to degraded dispatch forecast performance. Whenever SCADA inputs are suspect, these systems default to a weather prediction only forecast. This affected 63 generation site forecasts, but it is not practical to identify how significantly the forecast performance was degraded due to the lack of actual SCADA data for comparison.
- Analog and SCADA dispatch – the dispatch forecasts for renewable generators in this category are produced from the EMS system (which is driven by SCADA data) and used by NEMDE. During the loss of SCADA, dispatch targets for these generators did not update, and instead defaulted to the last received target. This affected 11 generation sites.

7. Provision of information to the market

Two Market Notices were issued regarding this event:

- Market Notice 82330 was issued at 1633 hrs on 24 January to advise the market of the SCADA issues, around 47 minutes after the AEMO SCADA system had failed at 1546 hrs.
- Market Notice 82340 was issued at 1708 hrs on 24 January to advise the market the SCADA issue had been resolved, 12 minutes after AEMO's SCADA system had returned to normal operation.

A recommendation is included in this report for AEMO to review whether broader communication relating to IT incidents to the market could be issued in a more timely manner.

8. Application of market suspension procedures

AEMO, in consultation with TNSPs, monitored errors in dispatch outcomes against AEMO's Failure of Market or Market Systems procedure[13].

Table 5As detailed in Table 5 and elsewhere in this report, errors were not widespread or outside the required margins and market suspension was not warranted. Therefore, AEMO correctly did not suspend the market.

This incident highlighted practical difficulties with the criteria listed in Table 5 during a NEM-wide loss of SCADA. AEMO has undertaken a review of the criteria (in consultation with industry) to simplify the criteria and ensure that they are more easily tracked during complex and challenging system incidents. The updated Failure of Market or Market Systems procedure was published on 11 June 2021.

below[14] summarises each of the criteria that was being monitored during the incident and outlines if each criterion was met. AEMO may only suspend the market if criteria 1, 2 and any of criteria 3 are met.

As detailed in Table 5 and elsewhere in this report, errors were not widespread or outside the required margins and market suspension was not warranted. Therefore, AEMO correctly did not suspend the market.

This incident highlighted practical difficulties with the criteria listed in Table 5 during a NEM-wide loss of SCADA. AEMO has undertaken a review of the criteria (in consultation with industry) to simplify the criteria and ensure that they are more easily tracked during complex and challenging system incidents. The updated Failure of Market or Market Systems procedure was published on 11 June 2021[15].

Table 5 Market suspension criteria

Criteria	Criteria detail	Criteria met?
1	Six or more consecutive dispatch intervals have been missed, leading to a failure to communicate dispatch instructions to a significant proportion of Market Participants within the region.	No, Market Participants continued to receive dispatch instructions throughout the incident.
2	The appropriate IT system is not expected to be available within a further 10 minutes.	No, NEMDE continued to operate throughout the incident.
3	Changes in power system conditions since the last valid dispatch run result in errors in dispatch exceeding: • 200 MW in the New South Wales region (suspension in the New South Wales region only); or • 200 MW in the Victorian region (suspension in the Victorian region only); or • 150 MW in the Queensland region (suspension in the Queensland region only); or • 80 MW in the South Australian region (suspension in the South Australian region only); or • 80 MW in the Tasmanian region (suspension in the Tasmanian region only); or • 350 MW in two or more regions (suspension in all regions).	There were dispatch errors exceeding the values stated here in some dispatch intervals. These errors were due to PFR enabled generators correctly drifting from their targets in line with their PFR settings to maintain system frequency closer to 50 Hz. As stated above, meeting criterion 3 in isolation does not meet the overall requirements for AEMO to consider market suspension.

[13] The current version of SO_OP_3706 is available on AEMO's website, at https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/power-system-operation/power-system-operating-procedures.

[14] This table contains the key market suspension criteria that were in place during the incident. The SO_OP3706 document has been updated post this incident so the criteria listed in the current live document have now changed.

[15] The current version of SO_OP_3706 is available on AEMO's website, at https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/power-system-operation/power-system-operating-procedures.

9. Other IT-related events

Operation of the NEM and its associated market systems relies heavily on IT systems. As highlighted in this report, IT systems play a key role in AEMO's SCADA, market operations, AGC, demand forecasting, and renewable forecasting systems. AEMO needs these IT systems to operate the NEM efficiently and safely.

Due to the prevalence of IT systems, when these systems fail, they have the potential to lead to power system and market impacts including:

- Missed/incorrect dispatch intervals.
- Market impacts affecting pricing outcomes.
- Constraint violations or constraint input failures.
- Missed/incorrect forecasts.
- Loss of visibility of power system alarms or status.
- Loss of communications with TNSPs.
- Mal-operation of special protection schemes.

AEMO is sharing additional information on IT issues to build awareness of the risks associated with operating a modern power system and demonstrate to the industry how AEMO manages those risks. This section of the report summarises notable IT issues that AEMO responded to between October 2019 and May 2021, including two other SCADA failures, with an overview of the recommendations identified and implemented in response to each these issues[16]. The power system remained in a secure operating state during all of these events.

9.1 Victoria loss of SCADA on 16 February 2021

This section is based on information from AusNet Services and from AEMO systems.

9.1.1 Incident overview

At 0703 hrs on 16 February 2021, all Victorian SCADA was lost at AusNet and subsequently AEMO. AusNet could log in to a limited number of displays and carry out limited switching operations using a secondary system. AEMO requested all large generators in Victoria to come off AGC and follow local targets. Victorian SCADA returned to normal operation at 0807 hrs on 16 February 2021.

9.1.2 Analysis

At 0459 hrs on 16 February 2021, one Victorian SCADA server failed due to a Solid-State Drive (SSD) failure. This initial server failure had no impact on Victorian SCADA due to system redundancy. By 0700 hrs, all Victorian SCADA servers had failed due to similar SSD failures, and this caused the loss of all SCADA relating to the Victorian transmission system. The loss of Victorian SCADA impacted the AusNet control room, the Murraylink runback control scheme, and AEMO's SCADA relating to the Victorian transmission system.

At 0703 hrs, Murraylink runback operated from 185 MW to 0 MW due to loss of the runback control scheme. This is the expected response from Murraylink when SCADA is lost.

While Victorian SCADA was unavailable, AusNet control room operators were able to log into a limited number of station human machine interfaces. In addition, the AusNet control room requested responders attend significant terminal stations to monitor and report back any alarms until the SCADA was restored.

[16] No separate reviewable incident reports will be produced for these two incidents.

At 0807 hrs on 16 February 2021, AusNet successfully restored its operational SCADA server, reinstating the Victorian SCADA system. At 1300 hrs on 16 February, an additional backup SCADA server was restored by Ausnet, reinstating redundancy to the Victorian SCADA system. At around 1200 hrs on 17 February 2021, AusNet reinstated its full SCADA service including full normal system redundancy.

Post incident investigation determined the root cause of the SCADA server failure as the SSDs' runtime being exceeded. The hardware manufacturer issued a firmware update for this condition. AusNet identified and updated all systems using this type of SSD. In addition, AusNet identified additional methods to allow SCADA to be recovered more quickly should a similar event occur in the future.

9.1.3 Market impact

While Victorian SCADA was unavailable, AEMO monitored interconnector flows and no gross dispatch errors were observed. The impact on the Victorian market was therefore minimal and the market was not suspended.

9.2 NEM SCADA Communications failure on 16 February 2021

9.2.1 Incident overview

At 1634 hrs on 16 February 2021, the SCADA communication links failed, resulting in all generating units in the NEM coming off the AGC system. The SCADA server process automatically detected an issue and restarted, and some SCADA communication links had already started to return when the market snapshot was taken for DI ending 1640 hrs. However, SCADA communications for 49 units had not yet returned, so these were not available to supply Regulation FCAS Raise and Lower services for DI ending 1640 hrs.

Following this event, a defect report was logged with GE and an updated software version was installed to prevent re-occurrence.

9.2.2 Market impact

Due to the reduced Regulation FCAS Raise and Lower service availability, mainland prices in these two markets spiked and reached $15,000/MWh (market price cap).[17] The failure did not have a material impact on prices in the energy market, with energy prices less than $65/MWh for all regions for the DI ending 1640 hrs.

Two constraints violated for DI ending 1640 hrs:

- F_TASCAP_LREG_0210.
- F_TASCAP_RREG_0220.

Both these constraints cap the contribution of Tasmanian generators to FCAS requirements. These constraints seek to ensure there is sufficient provision of regulation FCAS by generating units on the mainland[18].

These constraints violated because the 27 units that had returned to AGC were insufficient for the regulation requirements. For DI ending 1640 hrs, 155 MW of Regulation Lower service was available against a mainland requirement of 160 MW, while 142 MW of Regulation Raise service was available against a mainland requirement of 170 MW.

AEMO investigated this incident and determined that it did not constitute a scheduling error.

[17] Regulation FCAS prices in Tasmania increased by a lesser extent, $56.51/MWh (raise) and $23.00/MWh (lower) for DI ending 16:40 hrs.

[18] These constraints ensure that in the event of a contingency that separates Tasmania from the mainland, there will be sufficient regulation FCAS services available on the mainland. The Tasmanian contribution is capped at 50 MW.

9.3 Other minor events

A summary of other IT related events between October 2019 and May 2021 is provided in Table 6.

Table 6 Other IT-related events

Event	Description	Recommendation
Inadvertent error in EMS deployment, 14/10/2019	At 1828 hrs on 14 October 2019, all AEMO SCADA became frozen for around 14 minutes. AEMO was updating offline EMS systems and inadvertently deployed an update to the active EMS system, freezing all SCADA systems. AEMO promptly identified and rectified the issue, returning SCADA to service at 1842 hrs on 14 October 2019.	The following recommendations from this incident have been implemented: • A frequency display independent of SCADA has been added to the AEMO control room. • AEMO procedures have been updated to state that system updates (except emergencies) should be performed during office hours to ensure timely support is available if required.
NEMDE missed dispatch intervals, **21/1/2020**	At 1429 hrs on 21 January 2020, there was an interruption to some electricity market applications within a 10 minute window. Two dispatch intervals were missed (interval ending 1445 hrs and 1450 hrs), and corresponding 5-minute PD and PD PASA intervals were also missed. The incident was caused by an EMMS cutover to a virtual machine.	Following this incident, AEMO completed checks that alarm systems/processes are in place to identify and respond to events of this type promptly and effectively.
Frequency outside normal operating frequency band, 28/1/2020	At 1715 hrs on 28 January 2020, it was observed that AEMO's 5MDF was returning suspect values for the New South Wales region. The control room identified that suspect data from Bomen (a solar farm) was feeding into the New South Wales demand value, causing the data point to fail. Due to this data point failure, NEMDE defaulted to a back-up process using historic demand values and the initial region supply from the previous dispatch interval to forecast demand. This led to an increasing error between dispatched generation and actual demand. The AEMO control room took a number of actions to rectify the situation however these were ineffective. At 1830 hrs the EMS site was moved from New South Wales to Queensland and the NEMDE demand targets updated. During this incident, system frequency was above 50.15 Hz for around 28 minutes. The FOS was not met during this incident[19]. Given that no credible contingency or power system fault occurred, this incident was classed as a scheduling error[20].	The following recommendations from this incident have been implemented: • AEMO completed a review of the data loading process when commissioning new stations to minimise the chance of re-occurrence. • AEMO created an additional real-time data monitoring screen for use by the AEMO control room.

[19] See https://www.aemc.gov.au/sites/default/files/2020-01/Frequency%20operating%20standard%20-%20effective%201%20January%202020%20-%20TYPO%20corrected%2019DEC2019.PDF.

[20] Additional information on this event can be found in Section 4.2.1 of the Q1 2020 frequency and time error monitoring report, at https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/ancillary_services/frequency-and-time-error-reports/quarterly-reports/2020/frequency-and-time-error-monitoring-quarter-1-2020.pdf?la=en.

Event	Description	Recommendation
Loss of AC supply, 29/1/2020	At 1116 hrs on 29 January 2020, the EMS active site was transferred from Queensland to New South Wales. At 1120 hrs, the DI for 1125 hrs was published but no FCAS regulation was dispatched in the NEM mainland. At 1121 hrs, the EMS active site was transferred back to Queensland and Regulation FCAS was dispatched across the NEM from DI 1130 hrs onwards. It was identified that a temporary AC supply failure had occurred affecting the New South Wales control room at 0705 hrs on 29 January 2020. This AC supply failure triggered mainland AGC suspension at the New South Wales control room, which required a manual reset. At 1140 hrs on 29 January 2020, the New South Wales control room AGC was manually reset.	AEMO installed alarms at the New South Wales control room to alert staff when the power supply is interrupted and switched onto the Uninterruptable Power Supply (UPS).
Failover of EMS, 5/3/2020	At 1419 hrs on 5 March 2020, there was a connectivity issue with the Queensland control room active EMS session. This caused an application task to crash and various other applications to abort. Automatic failover to the Queensland number 2 session occurred as designed. As a result of this issue there was no active AGC session in the 1425 hrs DI and no regulation FCAS was dispatched in the NEM for the 1425 hrs DI.	AEMO redundancy systems performed as expected during this incident – no recommendations.
No Regulation FCAS dispatch in the NEM, 16/4/2020	From 1720 hrs to 1820 hrs on 16 April 2020, there was no Regulation FCAS dispatched in the NEM. This was caused by a failover at 1715 hrs moving the active EMS session from New South Wales to Queensland to facilitate some routine database works. At 1726 hrs, the active EMS session was moved back to Queensland to try and resolve the issue, but this was ineffective. At 1820 hrs, the AGC system in Queensland was manually restarted and then the active EMS session was moved to Queensland; this rectified the issue[21].	The following recommendations from this incident have been implemented: • Defect was logged with software provider and an update patch installed. • AEMO has implemented an additional monitor for the status of AGC for use in the control room.
AEMO AGC paused, 14/10/2020	From 0448 hrs to 1730 hrs on 14 October 2020, an outage occurred on Basslink. During this period the Tasmanian frequency remained within the normal operating frequency band at all times, however, frequency stability was notably less consistent than expected, exhibiting a wide oscillating behaviour. In an attempt to identify the root cause of these oscillations, AEMO paused dispatch of Regulation FCAS in Tasmania for the DIs ending 1245 hrs and 1250 hrs, however the oscillations continued. During the two DIs in which AEMO had paused the Tasmanian Regulation dispatch, no Regulation FCAS was dispatched in Tasmania. AEMO subsequently retuned the AGC frequency bias setting in Tasmania and this successfully reduced the observed frequency oscillations[22].	No recommendations identified.
Failover of EMS, 6/1/2021	On 6 January 2021, no Regulation FCAS was dispatched for the DIs ending 1255 hrs and 1300 hrs. This occurred during an unplanned failover of AEMO's EMS system. The status of AGC units was flagged as suspect following the failover which led to no Regulation being dispatched. The failover was caused by AEMO control room operator error. The data quality issue was rectified following an automatic restart of the failed server.	AEMO restricted control room access to process manager to reduce the risk of re-occurrence.

[21] Additional information on this event can be found in Section 6.3 of the Q2 2020 frequency and time error monitoring report, at https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/ancillary_services/frequency-and-time-error-reports/quarterly-reports/2020/frequency-and-time-error-monitoring-2nd-quarter-2020.pdf?la=en.

[22] Additional information on this event can be found in Section 4.5.2 of the Q4 2020 frequency and time error monitoring report, at https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/ancillary_services/frequency-and-time-error-reports/quarterly-reports/2020/frequency-and-time-error-monitoring-4th-quarter-2020.pdf?la=en.

A1. SCADA, EMS, and EMMS Systems

A1.1 Summary of SCADA/EMS Environment

SCADA control system architectures are widely used to manage process and operational systems. In the NEM, SCADA information is sourced from field devices, updated approximately every four seconds, and input into operational systems and displays for use by operational staff. AEMO does not source SCADA information directly from the field devices, but rather from the asset owners, such as NSPs. The asset owners' SCADA systems were not impacted by the failure of AEMO's SCADA systems during the 24 January 2021 incident.

The AEMO NEM SCADA/EMS environment consists of eight servers located over two sites. At any one time, two of these servers are active, with the remainder available on standby. The standby servers are kept in synchronism with the active servers via an automated copying process. This environment and copying process facilitates backup and redundancy across the separate sites and servers.

A1.2 Energy Management System (EMS)

The EMS displays the status of the power system – including line flows, system voltages and frequency, and equipment status – and provides real-time analysis tools for AEMO control room staff to monitor and assess the status of the power system. The SCADA information is also used in a number of power system analysis tools to help ensure the power system remains in a secure operating state. The EMS requires SCADA to update in a timely fashion with the correct information, otherwise the information it displays may not accurately represent the status of the power system.

A1.3 Electricity Market Management System (EMMS)

The EMMS calculates the dispatch level of generators and interconnectors, and regional energy and FCAS prices on a 5-minute dispatch interval basis. The EMMS also provides pre-dispatch (or forecast dispatch outcomes) and reserve levels for up to the next 24 hours. SCADA information is one of the major inputs to these processes.