MINUTES

MEETING:	NATIONAL ENERGY MARKET OPERATIONS COMMITTEE | NEMOC
DATE:	Thursday, 27 April 2023
TIME:	1PM – 4PM (Sydney / Melbourne Time)
LOCATION:	Online / Microsoft Teams
TELECONFERENCE DETAILS:	Microsoft Teams By phone: +61 2 8318 0090,,782582807#

ATTENDEES:

NAME	COMPANY DEPARTMENT	NAME	COMPANY DEPARTMENT
Tjaart Van der Walt	AEMO *(Chair)*	Christiaan Zuur	CEC
Danielle Freke	AEMO *(Secretariat)*	Laurent Francisci	CEC/Neoen
Michael Gatt	AEMO	Gary Adkins	ElectraNet
Ken Harper	AEMO	Verity Watson	ENA
Teresa Smit	AEMO	Glenn Springall	ENA (DNSP Rep) /Energy QLD
Ben Skinner	AEC	Emma Rogers	Powerlink
Naresh David	AEC/Energy Australia	Jason Krstanoski	Transgrid
Tim Lloyd	AusNet Services	Jason King	TasNetworks

GUESTS:

NAME	COMPANY DEPARTMENT	NAME	COMPANY DEPARTMENT
Daniel Lavis	AEMO	Mark Miller	AEMO
Darren Spoor	AEMO	James Guest	AEMO
Nilesh Modi	AEMO	James Lindley	AEMO
Sujeewa Rajapakse	AEMO	Will Drummond	PwC
Callan Masters	AEMO	Matthew Hunt	PwC
Harmohan Singh	AEMO	Alice Newbold	PwC
Jenny Riesz	AEMO	Nick Burjorjee	PwC
Luke Robinson	AEMO	Doug Thomson	Transgrid
Garry Tuckwell	AEMO	Jahan Peiris	Transgrid

1 WELCOME

Tjaart welcomed members to the meeting and noted the apologies.

2 PREVIOUS MINUTES AND ACTIONS REGISTER

- Previous meeting minutes (9 December 2022) were accepted with no changes made.
- Actions Register was reviewed and actions amended accordingly.

3 DEEP DIVE DISCUSSION – COMMISSIONING PRESENTATION

LUKE ROBINSON, DOUG THOMSON, JAHAN PEIRIS

- The commissioning presentation 'Coordinating large-scale changes in NEM capacity' was to open discussion on where we're going and how we're going to coordinate this vast installation of renewables and how do we work

together to actually make sure that we don't risk the power system, but we actually don't slow it down either the installation of these.

- A copy of the presentation is included at the end of these Minutes.

4 INERTIA MEASUREMENT TRIAL DISCUSSION

MARK MILLER, NILESH MODI JAMES GUEST, JAMES LINDLEY

- Mark Miller did a presentation on the Victorian Inertia Measurement Trial.
- Pilot testing was meant to start today on 27 April but that has been moved back to mid-May.
- A copy of the presentation is included at the end of these Minutes.

5 PRIORITISATION OF WORK STREAMS FOR DIFFERENT WORKING GROUPS

- Members discussed the below top priorities of planned activities from the NEMOC Working Groups for NEMOC endorsement.

NEM EMERGENCY COMMUNICATIONS WORKING GROUP (NEMEC)

- Seeking NEMOC approval for the initial HF installation (NEMEC recommendation).
- Testing the HF communications following the installation at preferred control rooms.
- Finalising the short-hop communications plans.
- Finalising the Emergency Communications Roadmap.
- Options yet to be considered for Communication with Government Energy Departments.

POWER SYSTEM SECURITY WORKING GROUP (PSSWG)

- Protocols for loss of communications.
- Cloud cover for reclassification frameworks.
- Space weather (BOM) will be meeting with the PSSWG prior to the planned space weather exercise in May 2023.
- Supporting TasNetworks with their RPSS obligations.
- Continue to review non-credible contingencies to identify systemic risks to system security.

OPERATIONS PLANNING WORKING GROUP (OPWG)

- Refine network outage planning process and introducing strategic improvements.
- Establish/refine operational processes for maintaining system strength and inertia of the power system.
- Improvements to network rating advice by NSPs to AEMO.
- Streamline NSP advice of power system project information to AEMO.
- Address emerging operational issues impacting power system security.

POWER SYSTEM MODELLING REFERENCE GROUP (PSMRG)

- Review of the Power System Model Guidelines.
- Transition from Mudpack to SSAT for small signal stability assessment.
- PSCAD version 5 improvements.
- Load performed standards (now being progressed through Connection Reform Initiatives).
- Modelling of inverter-based loads.

OPERATIONS TRAINING WORKING GROUP (OTWG)

- Power System Operator Training Framework (PSOT).
- ToR for the OTWG and Steering Committee.
- Sharing and collaboration of current control room training practices and content between AEMO and Participants.
- Training impacts and needs to achieve NEM 2025 Objectives.

- It was agreed by members to have a one hour out-of-session NEMOC Meeting for members to prioritise what NEMOC thinks are the top five priorities that each of the Working Groups should be focusing on.

ACTION – Secretariat – Set up a one hour out-of-session meeting with NEMOC Members to prioritise what NEMOC thinks are the top five priorities that the Working Groups should be focusing on.

6 WORKING GROUP UPDATES

- Power System Modelling Reference Group (PSMRG) did not present but gave an update prior to the Meeting informing members that there hasn't been a PSMRG Meeting since the last update given at the last NEMOC Meeting (9 December 2022) by Mark Gordon. Mark Gordon was the previous convenor of PSMRG but he has since left AEMO. PSMRG is in the process of electing a new convenor.
- All Working Groups were asked to assign deliverable dates to what they are working on and report back with these at the next NEMOC Meeting.

ACTION – Working Groups to assign deliverable dates to what they are working on and report back with these at the next NEMOC Meeting.

6.1 NEM EMERGENCY COMMUNICATIONS WORKING GROUP (NEMEC WG) *HARMOHAN SINGH*

i. LONG-HAUL COMMUNICATIONS OPTIONS

- The NEMEC has now completed a review of the options to cover the long-distance communications requirements in the NEM. This has concluded that HF radio links are likely to be the most reliable and economic means of complying with the System Restart Communications Protocol.
- It is proposed that a 400W HF radio system should be installed in Brisbane control room and Tasmania. This test system would enable communications between AEMO and TasNetworks over a six-month period. Commonwealth funding is presently being sought for this trial.

ii. SHORT-HAUL COMMUNICATIONS

- The NEMEC discussed the requirements and options for short-haul communications within a region. It was agreed that much of this communication would need to be coordinated through the TNSP.
- The NEMEC concluded that the following list of participants in the NEM would need to have access to these communications links.
    - Owners of Synchronous Condensers.
    - SRAS Operators.
    - TNSPs / DNSPs / MNSPs.

- Scheduled generators.
- Government Energy Departments.

- Note that the following participants have been excluded as these are generally not considered "restart participants" as per the System Restart Communications Protocol.
  - Semi-scheduled generators.
  - Non-scheduled generators.
  - Distributed Energy Resource (DER) aggregation.
- The options to provide these short-haul requirements will be considered at the next meeting.

iii. EMERGENCY COMMUNICATIONS

- The options to provide the Emergency Communication with Government Energy Departments will be considered at the next meeting.
- The proposed HF option would use 400W equipment with digital signal processing and selected commercial frequency bands.

iv. NEXT MEETING

- TBC.

v. MEMBER QUESTIONS AND DISCUSSION

- Jason King raised the point if SCADA was down, what other modes do we actually need to bring a network back into a state where we have some observability – whether through data or voice?
  - Ken mentioned that James Guest is looking at this issue over the coming months on how we could use PMU data better in these type of instances.
- Harmohan asked NEMOC to endorse the testing for the long-haul communications high frequency radio systems?
  - Tjaart reminded Harmohan that anything that NEMEC wishes NEMOC to endorse to add that in the WG discussion paper as a 'call to action'? Testing was given the go ahead but NEMEC needs to update NEMOC at the next NEMOC meeting on the Commonwealth funding status and cost details.
  - Harmohan advised Indicative costs to install two long-haul communications 400W HF radio systems – $250,000.
- Verity and Christiaan raised the point that the short-haul communications process should go through AEMO's Connections Reform Review of the access standards.
  - Harmohan said he will update members at the next NEMOC meeting as NEMEC is still working through the short-haul requirement options and these will be discussed at the next NEMEC Meeting.

ACTION – (1) Harmohan to add 'a call to action' in the NEMEC WG discussion paper if NEMEC is asking NEMOC to endorse something. (2) Harmohan to update NEMOC at the next meeting on the Commonwealth funding status and cost details for the long-haul communications high frequency radio systems. (3) Harmohan to update NEMOC on the status of the short-haul requirement options and engage the AEMO team leading the Connection Reform Review so that the communication capabilities are accounted for in the access standards review.

6.2 POWER SYSTEM SECURITY WORKING GROUP UPDATE (PSSWG) *DARREN SPOOR*

i. NETWORK RECLASSIFICATION CRITERIA

- The working group was also briefed on the work being initiated by AEMO Operations Forecasting to improve the visibility of cloud cover events on PV. This will lead to further discussion at the next meeting on the potential of a reclassification framework for cloud cover.

ii. INDISTINCT EVENT RECLASSIFICATION FRAMEWORK

- The PSSWG endorsed the publication of SO_OP_3715 (Power System Security Guidelines) at the last meeting. These were published by AEMO in March.

iii. GENERATOR RECLASSIFICATION CRITERIA

- SO_OP_3715 included a new section on generator reclassification requirements, based on the input provided by the Energy Council.

iv. LOSS OF VOICE COMMUNICATIONS

- The PSSWG discussed the potential impacts following a loss of voice communications between control centres. This discussion is currently coupled with the RPSS (Residual Power System Security) and will be discussed further at the next meeting.

v. LOSS OF TELEMETRY COMMUNICATIONS

- The working group is continuing to review a new draft section within SO_OP_3715 entitled "telemetry system outages covering general principles".

vi. INDUSTRY BEST PRACTICE FOR OPERATIONAL COMMUNICATION

- The PSSWG was previously briefed on the recommendations from the Control Room Operations Working Group (CROWG) on the industry best practice for operational communication. The PSSWG will continue this review at the next meeting.

vii. NEXT MEETING

- The next PSSWG meeting will be held on 12 May 2023.

viii. MEMBER QUESTIONS AND DISCUSSION

- Ben asked is the best practice for operational communication another investigation of what type of short-haul communications we need?
    - Darren said no, that best practice communication requirements document came out of the Control Room Operations Working Group last year, a heavily consulted process. It has been referred now to the PSSWG for ratification and endorsement and effectively includes items such as native langue, speaking of English and all the fundamental requirements to take a telephone call.
- Tjaart asked so the loss of telemetry communications, what is that about and how does that differ from the work the operations communications committee is doing?
    - Darren said the intent of the loss of telemetry communications discussion is to focus on requirements for each organisation, particularly the TNSP and AEMO on what to do if we lose SCADA. It's the response to losing communications. So general principle surrounding loss of SCADA, holding last known dispatch targets etc and not moving off and taking your own actions in the power system without verbally communicating them. These are industry best practices of the past, but they're not documented.
- Ben said this sounds like an appropriate piece of work and asked if this has been triggered due to the four big SCADA outages in the last 12 months?
    - Darren said the body of work was initiated last year but put on hold to focus on indistinct events and reclassification. But he'd argue that it was initiated as a result of some SCADA failures in 2021. Yes.
- Ken asked for completeness Darren, we have used a number of times recently the new indistinct framework event, haven't we? We've used it for solar reclass and a few other ones?
    - Darren said just for the solar eclipse in affecting primarily the wind.

6.3 OPERATIONS PLANNING WORKING GROUP (OPWG) *SUJEEWA RAJAPAKSE*

i. EXTREME FREQUENCY MANAGEMENT

a. UNDER-FREQUENCY LOAD SHEDDING (UFLS) REVIEW

AEMO Systems Performance completed the UFLS review, and it showed the existing UFLS settings are adequate. The outcomes of the review were presented to the OPWG. AEMO Systems Performance will present UFLS review outcomes to TNSPs as required.

b. IMPLEMENTATION OF OVER-FREQUENCY GENERATOR SHEDDING (OFGS) SETTINGS

- AEMO is working with ElectraNet to implement recommended OFGS settings for SA.

  Currently, ElectraNet is in discussion with relevant generators to update their OFGS settings.

- The OFGS review of QLD has just started and is currently in early study stage.

ii. TRANSMISSION EQUIPMENT RATING ADVICE PROCESS

The spreadsheet-based rating advise process being used is cumbersome hence AEMO has commenced a review. This review is intended to address immediate issues as well as to develop requirements for a more efficient long-term process. Improvements to the rating advice process in the WEM is also in scope.

AEMO documented the issues and pain points reported by NSPs to develop a business case. Held the first meeting between AEMO and NSPs including EMS/SCADA SMEs to discuss options for implementing improvements.

iii. EMERGING OPERATIONAL ISSUES

a. OBTAINING MODELLING AND LIMIT ADVICE AND TIMING

For generator and network changes, AEMO has timelines for obtaining modelling information and limit advice. Most of these timelines have been in place for many years – but not presented in a single document. AEMO is intending to publish these requirements in a table on AEMO's website. TNSPs supported this action because it would then be easy to explain the timeline requirements to all involved in major projects within their organisations.

b. OPERATION OF SEMI-SCHEDULED GENERATION

The OPWG discussed power system security issues caused by large increases of semi-scheduled generation in dispatch intervals immediately following dispatch intervals with semi-scheduled cap applied. The OPWG has developed a brief discussion paper on the available options to manage this.

The OPWG is seeking advice of NEMOC on the next steps to resolve this issue.

c. OBTAINING SYSTEM STRENGTH / MINIMUM FAULT LEVELS AT VARIOUS NODES OF THE POWER SYSTEM

AEMO discussed the need to obtain system strength / minimum fault levels various nodes of the power system under outage conditions, via limit advice. AEMO will commence work with TNSPs to establish a structured process for this shortly.

iv. PRESENTATIONS

- Introduction to AEMO Operational Technology Roadmap (Garry Tuckwell/AEMO).
- New Frequency Operating Std, Largest Generating Contingency in each region (Mark Stedwell/AEMO).
- Fast Frequency Response and the associated FCAS issues[1] (Carla Ziser/AEMO).

v. NEXT MEETING

The next OPWG meeting will be held on 7 June 2023.

ix. MEMBER QUESTIONS AND DISCUSSION

- Sujeewa sought advice from members on what steps should OPWG follow regarding their discussion paper on the available options in managing operation of semi-scheduled generation and the associated power system security issues.
    - Christiaan and Ben stated that it's important that any changes that are recommended need to be consulted on broadly and as widely as possible across the industry and as far as NEMOC is concerned, we endorse you doing that public consultation.
- Ben asked regarding timelines for obtaining modelling information, is it only for TNSPs affected by that or are there other parties?
    - Sujeewa advised that it's mostly for TNSPs.

[1] Further details on arrangements for Fast Frequency Response are available at: https://aemo.com.au/initiatives/major-programs/fast-frequency-response

6.4 OPERATIONS TRAINING WORKING GROUP (OTWG)

DANIEL LAVIS

i. POWER SYSTEM OPERATOR TRAINING FRAMEWORK (PSOT) – PILOT PROJECT

OTWG and the PSOT Steering Committee have selected 11 out of a possible 23 Fundamental topics to be included as a module development pilot project. The pilot is intended to test and develop the PSOT framework including the delivery, reporting and review mechanisms.

The selected list of modules was provided to Thomson Bridge – RTO for content development consideration, including:

1.1 Australian Networks and Elements of Electrical Power Systems

1.2 Renewables and Emerging Technologies

1.6 Electrical Fundamentals – AC

1.9 Electrical Fundamentals – Basic Electrical

1.12 Protection Fundamentals

1.13 Switching Fundamentals

1.14 Management and Coordination of Work Parties and Field Operators

1.15 Voltage Control and Reactive Power

1.17 Power Control and the Energy Market

1.20 Human Factors – Communications

1.23 Human Factors – Decision Making and Situational Awareness

Thomson Bridge is finalising a proposal for AEMO to progress the pilot.

ii. TRAINING COLLABORATION AND SHARING – POWER SYSTEM OPERATORS

AEMO recently hosted a visit of new trainee ElectraNet Controllers to the AEMO Brisbane Control Room, where AEMO's Power System Operators gave their perspective on operating the SA network. Feedback from staff of both organisations indicated this visit was significantly more productive than completing an online course or speaking with people over the phone and helped to foster good working relationships. Going forward, this should be considered by other TNSPs who are training new PSOs.

Part of the visit included an abridged version of SA System Restart training, which was understood to be a motivating factor for ElectraNet to progress their own simulator training.

It is envisioned that a Training Collaboration and Sharing program will be established under the OTWG to promote future opportunities including AEMO's planned System Restart training. These visits could be included as part of new TNSP Control Room Operator induction training.

Target – targeting new staff and look to retrospectively accommodate current staff, as availability allows.

Short term – existing Control Room operators visit AEMO/Participant control rooms to gain a broader perspective around operating the power system and participate in AEMO's System Restart training.

Medium to long term – based on the success of the visits by existing control room operators along with determination of scope and requirements, establish a formal program for new operators in the power industry, that can be undertaken in parallel with required modules of the PSOT framework.

iii. OWTG UPDATE

AEMO presented on The Roadmap to 100% renewables, that has identified the need for a significant uplift in industry training standards to ensure operator capability and sufficient training. The OTWG will be used to inform development and implementation of robust procedures and processes for the range of new operational tools and practices required.

The PSOT Framework is being designed to deliver against these objectives.

iv. NEXT MEETING

The next OTWG meeting is planned for June 2023.

v. MEMBER QUESTIONS AND DISCUSSION

- Ken asked we just completed last week, six sessions of Queensland system restart training and we had the most massive attendance of any restart sessions I've probably ever seen here in terms of participation from industry, customers and everyone. Would that be correct, Daniel?
    - Daniel said yes and what made it such a big attendance was the ability to provide the remote/online delivery of it, which we've refined and we've been able to get some great interaction from participants.
    - Jason King praised Daniel for his fantastic piece of work in getting the operating training to where it is today and he believed the onus is on the rest of us TNSPs to support this so that it continues and becomes successful.

7 INDUSTRY ENGAGEMENT FOR OPERATIONS TECHNOLOGY PROGRAM *GARRY TUCKWELL*

- Garry gave members an overview of the Operations Technology Program. Garry said by way of background, we published the Operations Technology roadmap in November last year and we then saw funding for that and then we've mobilised the team and the program to execute on what was sort of called out in the roadmap. The purpose of Garry's presentation was to give members a brief update on where we're up to.
- A copy of the presentation is included at the end of these Minutes.

8 PwC PRESENTATION ON RESULTS OF THE MARKET AUDIT *WILL DRUMMOND, MATTHEW HUNT ALICE NEWBOLD, NICK BURJORJEE*

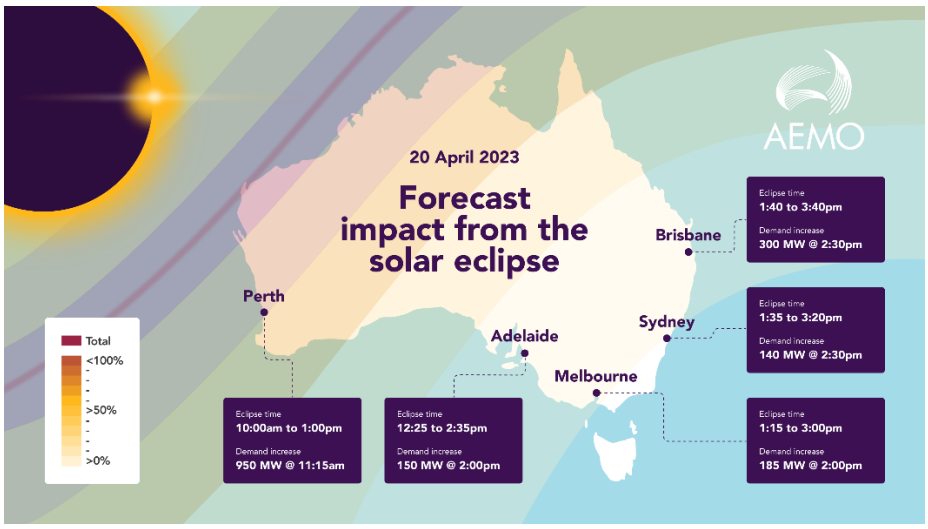
- The PwC presentation covered three areas: (1) the scope and objectives of the market audit, (2) to provide an overview of the key findings that came out and (3) to understand if there's any particular risks that market participants are aware of that they would desire a market audit to consider as part of the planning process.
- A copy of the presentation is included at the end of these Minutes.

9 SAFETY

- No safety issues were discussed.

10 GENERAL BUSINESS

Teresa Smit, AEMO's Group Manager – WA Operations, talked about the planning and experiences during the recent solar eclipse in WA. The majority of the South West Interconnected System (SWIS) experienced between 60–80% coverage. The impact of the predicted change in rooftop PV during the eclipse was incorporated into the load forecast and ancillary services procured to manage this. As expected, the magnitude of change was about 700 MW up and 950 MW down. This magnitude of change is of a similar range to that experienced during large cloud movements but could be carefully planned for. A summary of the event and key learnings will be made available to NEMOC members.



- Ken sent members the following link on where the upcoming eclipses big ones hitting parts of the NEM on 22 July 2028 and 25 Nov 2030. Link – Solar Eclipses in Australia (timeanddate.com).
- Tjaart advised members that they can put forward any deep dive topics they may wish to discuss.

11 MEETING CLOSE

- The meeting closed at 4pm.

MEETING / WORKSHOP	DATE
NEMOC MEETING No.32	9am – 12pm AEST Friday 23 June 2023 (Virtual)

Coordinating large-scale changes in NEM capacity

27 April 2023

NEMOC

Luke Robinson

Potential scope for discussion

1. Proposed timeframe for presentation / deep-dive: 30mins
2. Key issues to discuss:
    1. Definition of contingency limits for non-credible events (e.g. N-1-1, N-2, single substation risks, accounting for actions to re-secure the system) associated with large generator developments / REZ developments (Notes: Transgrid likely to lead this aspect of the discussion; also link to new FOS requirements).
    2. Work needed to coordinate transmission outages, and testing and commissioning of generation and network, including staged capacity release.
    3. Potentially significant changes to power flows, voltages and system operation in a relatively short period of time associated with large REZ developments.
3. Feedback sought:
    a. Is there a need to consider staged release of REZ capacity and a coordinated approach across NEM jurisdictions.
    b. Potential for routine power system testing rather than linking specific network and REZ developments to 5.7.7 testing.
    c. Potential joint development of a tool (similar to the AEMO augmentation tool) to assist with coordination.
    d. EJPC / NEMOC to share their thoughts on these issues, assign to relevant sub-groups to explore.
4. Key considerations & risks:
    a. Risk of delays due to complexity coordinating outages, coordinating commissioning across multiple projects and suitable testing conditions impacting proponent commissioning timeframes and overall capacity release.
    b. Technical risks, such as:
        a. Regular update of limits/constraints on a scale not experienced before
        b. Impacts on voltage management / Var Dispatch Scheduler (VDS)
        c. Dynamic Security Assessment (DSA) contingency definitions may need to be revised / expanded
        d. System damping impacts with new syncons and IBR displacing synchronous generators
        e. Power system model updates need to keep up with the changes

Discuss: NEMOC/EJPC feedback on the proposed discussion. Any key issues NEMOC/EJPC would like covered.

For more information visit

aemo.com.au

Victorian Inertia Measurement Trial

April 2023

Agenda

- Background
- Victorian Inertia Trial
- Power System Studies
- Procedure for Trial
- Next Steps
- Q&A

Background

Overview and Partnership

- A project trial to measure and estimate power system inertia was established and funded by ARENA in Late 2019
- Project stakeholders include:

Australian Government
Australian Renewable Energy Agency
ARENA
reactive technologies
VICTORIA State Government
Energy, Environment and Climate Action
NEOEN
AEMO
THE UNIVERSITY OF MELBOURNE

- Testing site: **Victorian Big Battery (Moorabool / VBB)**
- Reactive Technologies (RT) have proposed to inject a modulating power signal into the NEM using a BESS in Western Victoria to trial their inertia measurement technology.

Why?

- Increased visibility and general understanding of inertia and risks of low inertia.
- Identifying the operational benefits of measuring inertia in high IBR penetration grid.
- Understanding of Reactive Technologies measurement product and how they could deliver potential benefits to AEMO, NSPs and the NEM.
- Results might trigger potential solutions and a way forward:
  - Sufficient number of synchronous generators online?
  - Reserve, FFR, inertial market, condensers, curtailment?

Inertia Estimation and Measurement Methodologies

VIC Trial

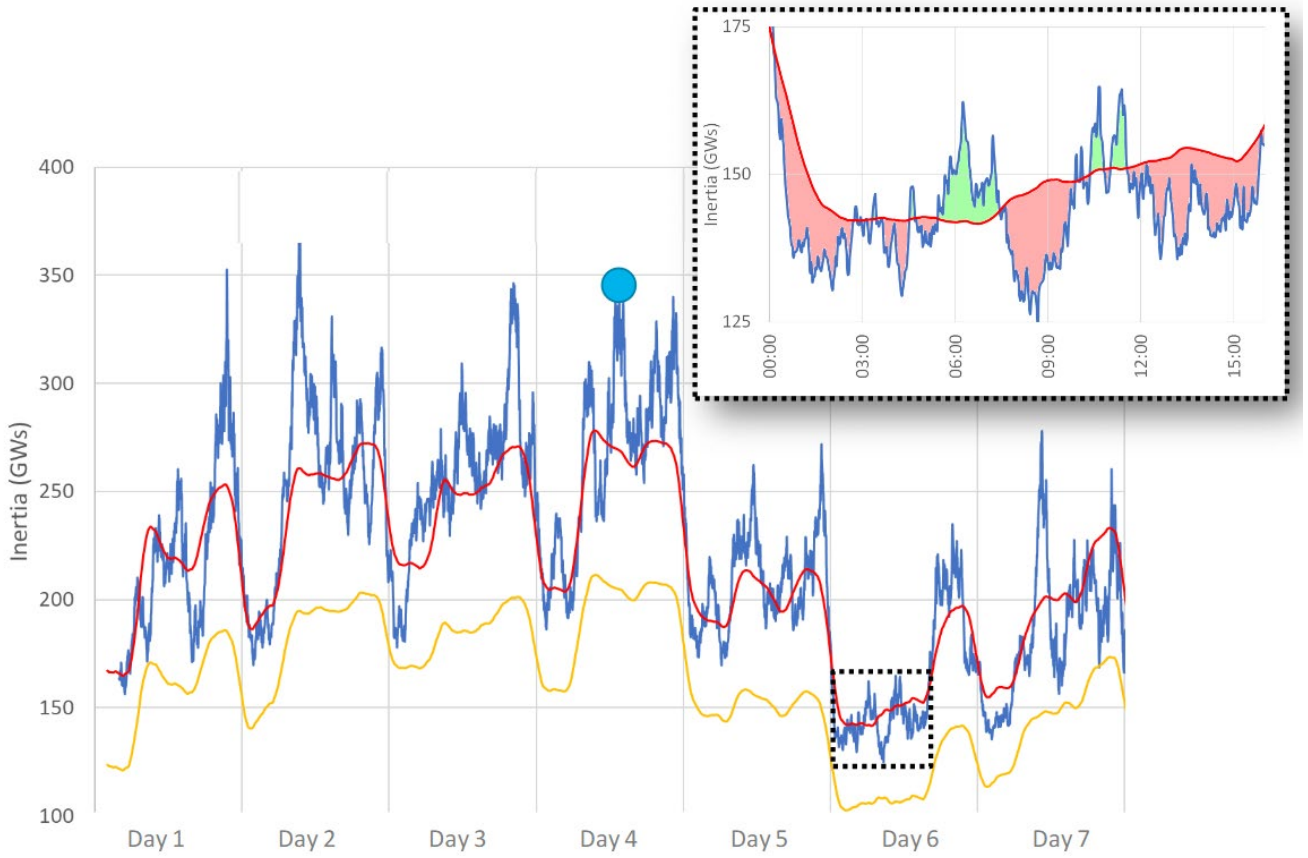
	Unit Commitment-Based Inertia Monitoring → AEMO	Inertia Estimation from Events → PMUs	Continuous Signal-Based Inertia Monitoring
Method	Summation of inertia constants (H) across all online generators	Calculate inertia based on RoCoF from event data (large loss events)	Uses batteries or ultra-capacitors to excite the grid with a small MW disturbances
Pros	• Relatively easy to implement and maintain • Good estimation	Includes damping factor, synthetic inertia and synchronous inertia	• Continuous measurement • Calculates inertia using the swing equation with a known ΔP and measured RoCoF
Cons	• Maybe overly conservative and rudimentary; • Inaccurate Inertia data leads to false estimation; • Neglects effect of demand inertia; • Neglects effect of 'digital inertia' (fast frequency response)	• Requires a large contingency event; • Not suitable for continuous or frequent measurement of inertia; • Could lead to errors based on measurement and interpretation; • Large events also effect voltage, therefore ΔP is affected	• Costly approach due to need for active power injection source; • Implementation of a continuous small active disturbance might not be suitable or safe

Overseas projects by Reactive Technologies

1. Project SIM - National Grid UK (5MW Super Cap) – fully operational since July 22
2. Inertia Measurement - TEPCO Case Study (Passive measurement)
3. TERNA - Sardinia Italy (1MW BESS)

Sum inertia constants: Inertia follows demand curve closely but under-reports level of inertia (so potential for over-spend on contingencies)

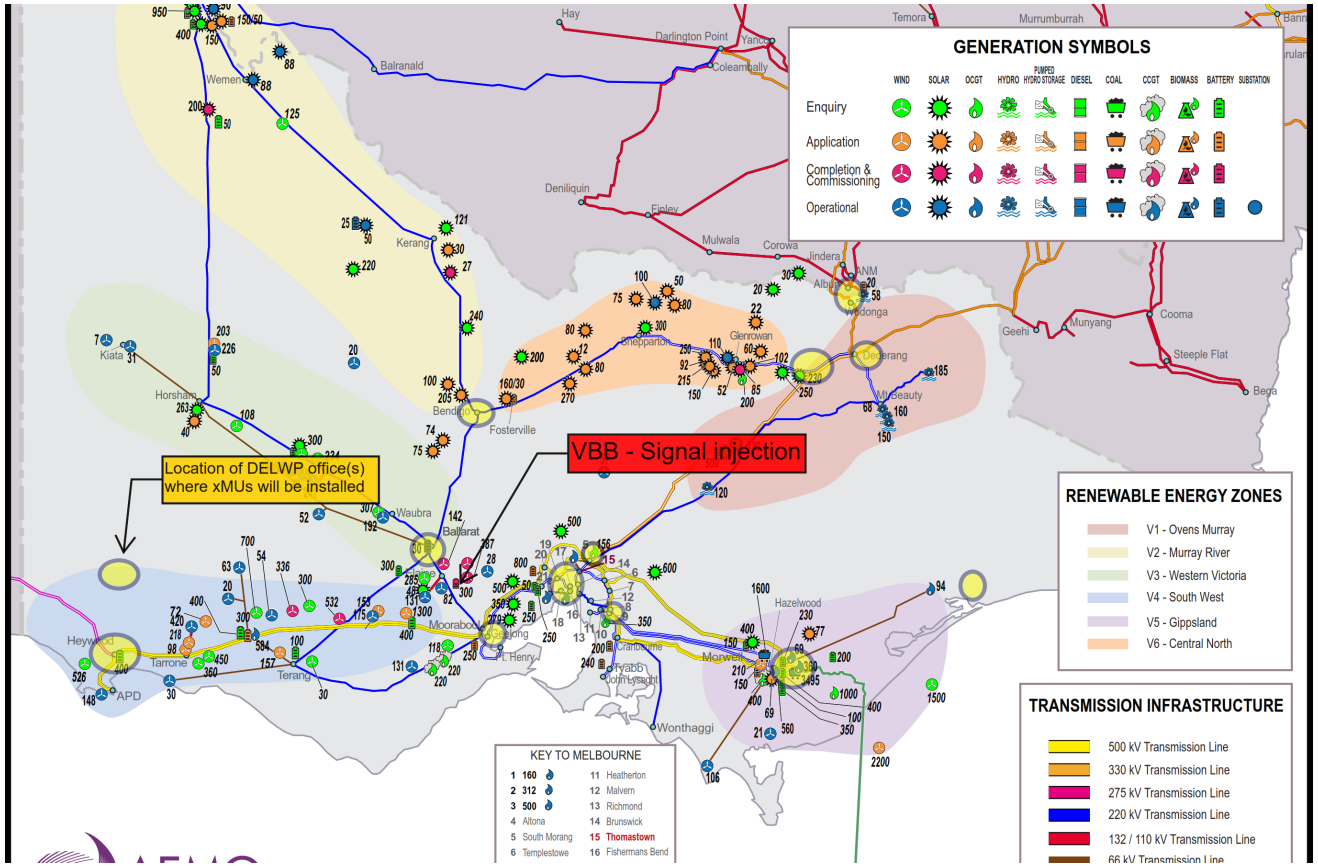
Model demand side: **'Scaling' factor** added to provide static view of real inertia level through inherent inaccuracy



Victorian Inertia Trial

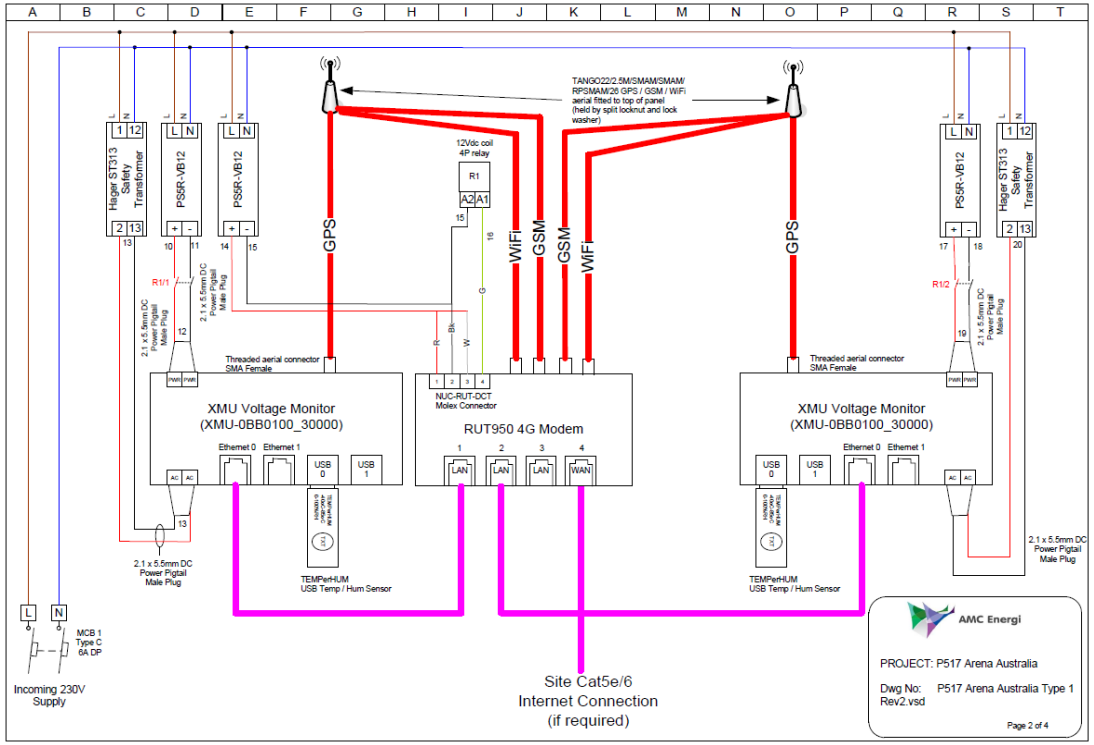
Measurement locations

- VIC Boundary points
- Total of ~15 locations:
  - East Melbourne
  - Heywood
  - Casterton
  - Irymple
  - Epsom
  - Wodonga
  - Wodonga
  - Ballarat
  - Beechworth
  - Traralgon
  - Bright
  - Geelong
  - Orbost
  - Heidelberg
  - Knoxfield



“Mini PMUs” deployed

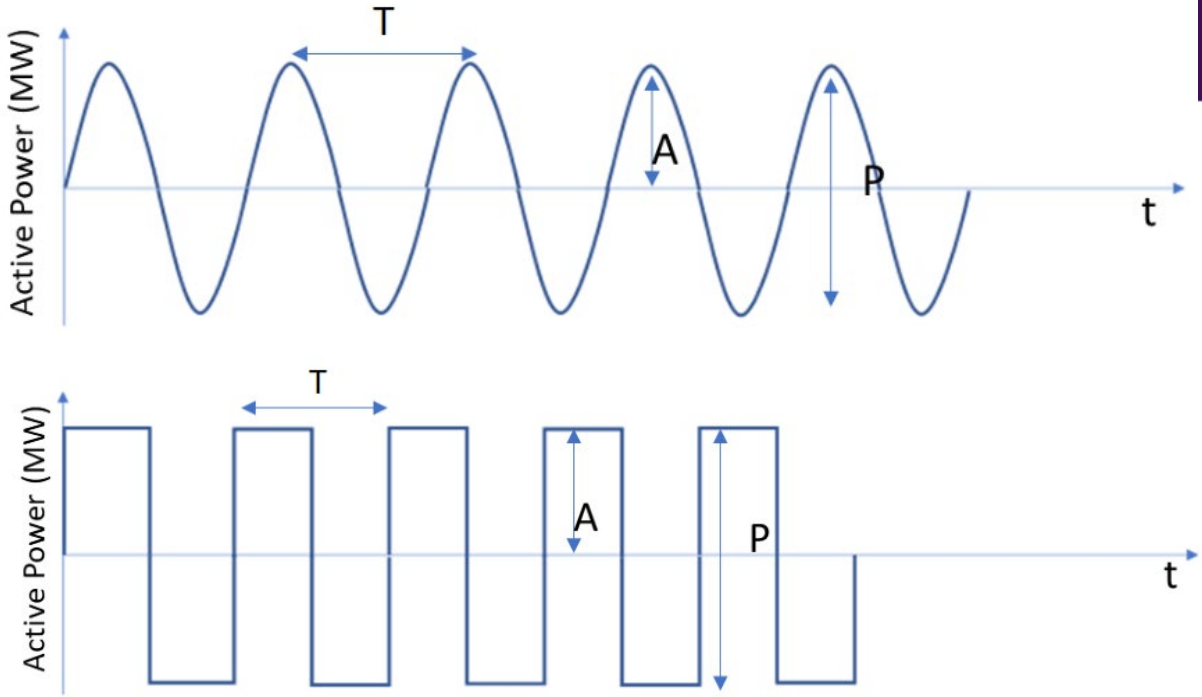
- Extensible multifunction unit (**xMUs**)
  - High Speed Voltage Magnitude, Phase and Frequency Measurement
  - Real time streaming up to 120 Measurement Results per Second
  - Secure Cloud connection using Data Encryption and VPN Connection
  - Remote configuration and provisioning by Reactive Technologies
  - GPS capability for accurate time synchronisation
  - Sampling rate up to 48kHz, 16 bit resolution
- Plugged in to 220V wall sockets (only in VIC)



Modulation test signal

- The modulator shall output two distinct modes of operation:
  - **Sinusoidal** wave with active power output
  - **Square wave** with active power output

Parameter	Minimum Value	Maximum Value
A (MW)	0MW	10MW
T (s)	5s (i.e. 0.2 Hz)	10s (i.e. 0.1 Hz)



Potential challenges

- The NEM has known oscillatory modes which should be avoided during modulation to prevent negatively damped resonance from occurring.

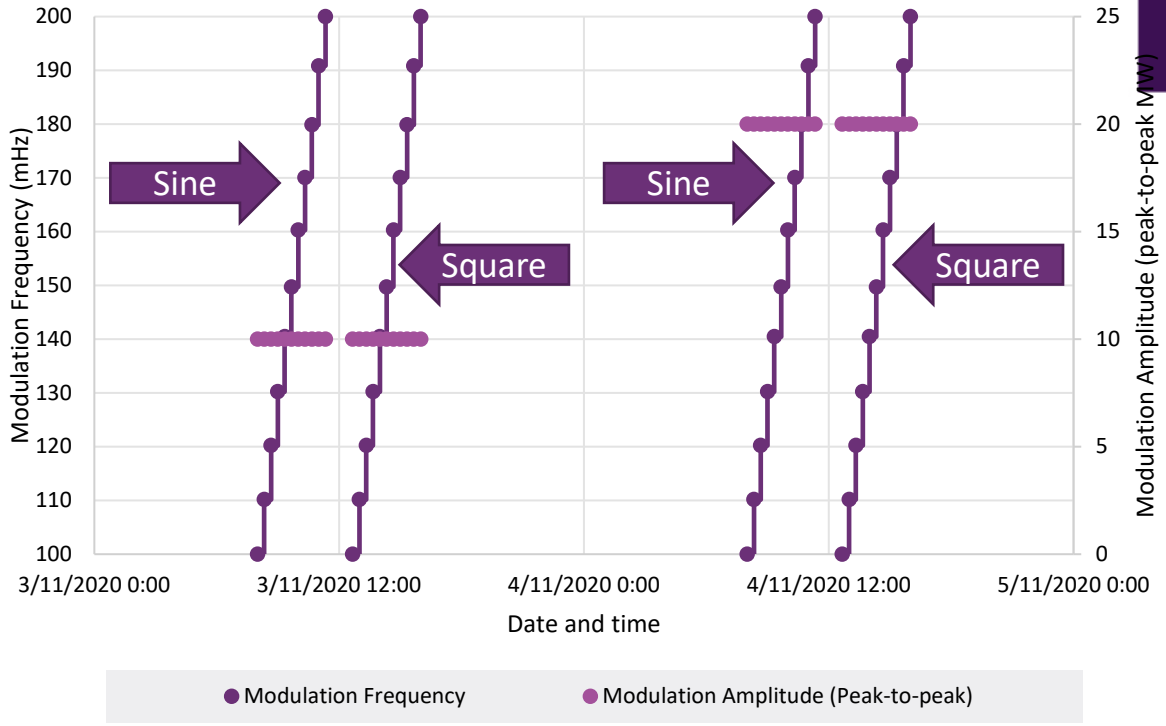
Inter-area mode	Frequency range		Frequency range		Participating groups of generators
	From (rad/s)	To (rad/s)	From (Hz)	To (Hz)	
QNI / I20	1.6	2.2	0.255	0.35	QLD oscillates against the other three states
I25	2.4	3.1	0.382	0.493	SA and QLD oscillate primarily against NSW
I35	3.2	3.8	0.509	0.605	SA and NSW oscillate against VIC

Pilot Testing – Commissioning

Modulation Frequency Sweep Test

- **Start** April 27 after SIPS
- **Commissioning**: Over 5 days Low Power Modulation Frequency Sweeps tests are proposed
- Duration of test signal:
  - Day 1-3: 20min per sweep
  - Day 4-5: 180min per sweep
- To verify the frequency behaviour of the grid and validate simulation studies.
- **Risk assessment:** RMS and EMT studies, live observation, Emergency stop if required

Modulation and frequency profile for the frequency sweep tests



Pilot Operational Testing

- Testing to commence: May – August 2023 after commissioning completed.
- Continuous testing limited to 60hrs per 4 week.
- Scenarios to be covered (for example):
  - Day: High share of IBR, low synchronous inertia
  - Day: High share of IBR, med-high synchronous inertia
  - Night: Low share of IBR, med-high synchronous inertia
  - Night: Med-high share of IBR (e.g. strong winds), med synchronous inertia
  - Night-Day-Night: Transition periods morning and afternoon and 24h
- **Risk assessment:**
  - Live observation
  - Emergency stop if required

Trial Risk Management

- The procedure for the Trial includes specific steps to manage residual risk through:
  - Initial pilot tests and initial assessment.
  - Real time monitoring of power system oscillations during tests by both Reactive Technologies and AEMO.
  - On going monitoring of power quality during tests.
  - Emergency stop process which can be initiated by AEMO Test Co-Ordinator including remote shutdown from NEOEN control centre.
  - Procedure provides guidance as to the type of events that would trigger a stop.
  - AEMO Test Co-Ordinator and Test Leader in attendance at all times during testing.

Power System Studies

Small Signal Stability Analysis – MUDPACK studies

- Magnitude responses for the transfer-functions from the BESS power-order input to a variety of power, frequency/rotor-speeds and voltage-magnitudes are calculated:
  - On the basis of a ±15 MW (30MW peak to peak).
- Harmonic components of proposed square wave injections:
  - The 3rd and 5th harmonics of square wave injections in the frequency range from 0.1 to 0.2 Hz can be expected to occur around interarea modal frequencies. Neglecting phase cancellation, the amplitudes of the 3rd and 5th harmonics is 1/3 and 1/5 respectively of the amplitude of the fundamental.

Results of Mudpack Studies

- Known NEM modes of oscillation are not expected to be exacerbated.
- Largest resonance is predicted to be at Blackwell in Queensland.
- At Blackwell a +- 10MW modulation is expected to result in a voltage fluctuation of +- 0.13%
- Studies have not identified any issues regarding small signal stability.
- Studies were conducted on basis of modulation signal at the Bulgana battery. The results for use of VBB should be similar.

PSCAD studies (v5 – 4 state model)

Scenarios considered

1. Low demand in VIC. North flow on VNI and east flow on HIC.
2. High demand in VIC. South flow on VNI and east flow on HIC.
3. Low demand in VIC. South flow on VNI and west flow on HIC.

VBB dispatch

OP	Description
Neutral	$P_{dispatch}$ of VBB=**0 MW** ±10 MW @ 0.1-0.2 Hz
Charging	$P_{dispatch}$ of VBB=**-240 MW** ±10 MW @ 0.1-0.2 Hz
Discharging	$P_{dispatch}$ of VBB=**+240 MW** ±10 MW @ 0.1-0.2 Hz

Contingencies

Cont.	Description	PSCAD ID #
1	Fault trip Heywood-Southeast	53900
2	Fault trip Buronga-Red Cliffs	23082
3	Fault trip Kerang-Bendigo	32081
4	Fault trip Dederang-South Murray	356090
5	Trip Kerang SVC	342081
6	Trip Horsham SVC	334081

Results of PSCAD Studies

The worst fluctuations observed in the PSCAD studies were:

- NSW-Vic Interconnector 0.5% voltage and 16MW (in a flow of 1600 MW)
- Darlington Pt 330kV bus 0.5% voltage
- Finley Solar Farm 0.6% voltage

These are considered acceptable.

Next Steps

Next Steps

- Commissioning and implementation of modulation mid-April 23.
- Pilot Commissioning Testing to determine optimum settings 27 April 23 to 3 May 23.
- Trial to run from early May to mid-August 23.
- Assessment and reporting from late August to late September 23.
- Verification of results by Melbourne Energy Institute.

External Communication

- AEMO Communication will be issued with link to information on the AEMO Website.
- Updates on progress of the trial will be provided on a monthly basis through AEMO Communications.
- A Market Notice will be issued if a significant issue arises due to the Trial.
- Information on the outcome of the assessment of the Trial will also be provided via an AEMO Communication.

Conclusion

Summary

- xMU's have been successfully dispatched and installed.
- Assessment has not found any material concerns based on the introduced modulation signal at Bulgana and/or VBB.
- Inertia measurement trial to begin April 23.
- Knowledge exchange with National Grid ESO:
  - A similar trail has been successfully completed in the UK
  - Utilising a 5MW Super-Cap as modulator (instead of a BESS), funded by National Grid
  - Real-Time inertia measurement service has been running live since 9 July 2022

Q&A

Please forward any further questions and concerns to Inertia.Trial@aemo.com.au

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For more information visit

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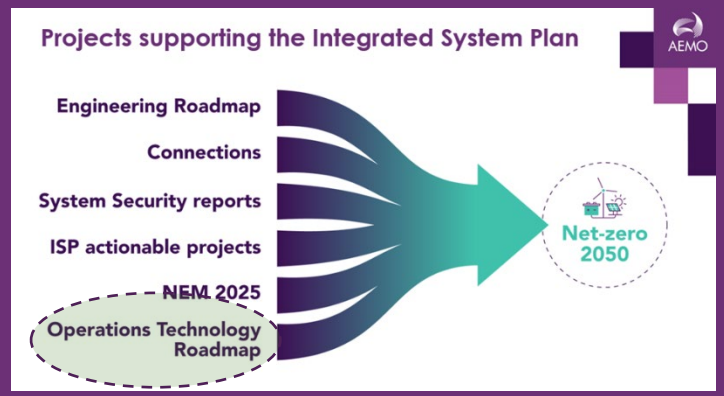


Operations Technology Program

NEMOC

27 April 2023

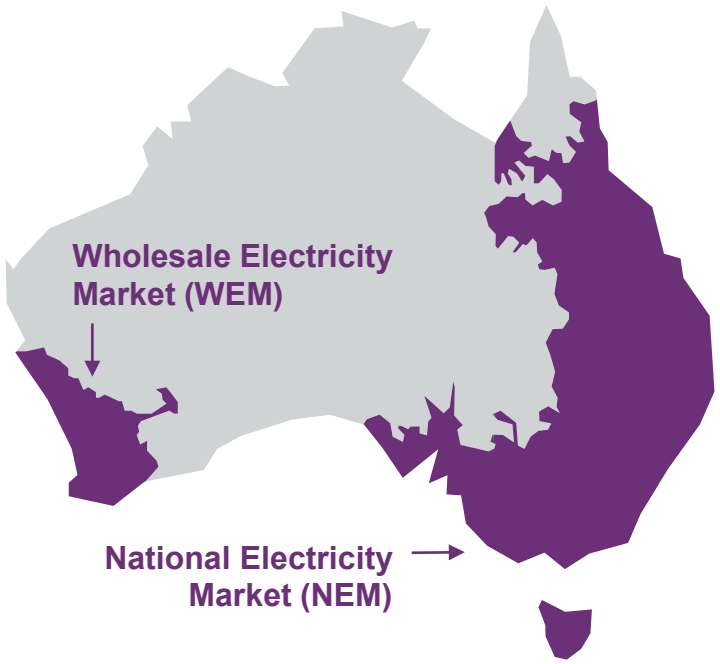
About AEMO

- AEMO is a member-based, not-for-profit organisation.
- We are the independent energy market and system operator and system planner for the National Electricity Market (NEM) and the WA Wholesale Electricity Market (WEM).
- We also operate retail and wholesale gas markets across south-eastern Australia and Victoria's gas pipeline grid.

AEMO SERVICES

AEMO Services is an independent subsidiary of AEMO, established in 2021 to enable the transparent provision of advisory and energy services to National Electricity Market jurisdictions.

Electricity



Gas

Declared Wholesale Gas Market (DWGM)

Short Term Trading Market (STTM)

and

Gas Supply Hub (GSH)

Our Priorities

PRIORITY 1

Operating today's systems and markets

PRIORITY 2

Navigating the energy future

PRIORITY 3

Engaging our stakeholders

PRIORITY 4

Evolve the way we work

Strategic Objectives

Priority 1 – Operating today's systems and markets

Deliver our core responsibilities in accordance with electricity, gas and other laws and regulations.

Our primary role is to ensure that Australia's energy systems and markets are operated reliably and securely every day.

In an environment where day-to-day operation of the nation's energy systems and markets has never been more challenging, AEMO will maintain our focus on constantly adapting our operations through FY2022 and meeting this ongoing commitment to Australian consumers.

We will maintain and enhance our focus on effective real-time system and market operations, power system resilience, cyber security and robust market and system intelligence.

How we will achieve this priority:

1. System and market operations

We ensure Australia's energy systems and markets can be securely and reliably operated under all foreseeable conditions.

In addition to delivering effective day-to-day real-time system and market operations, AEMO will:

- **Engage on, and manage emerging power system resilience issues** through cost-effective measures that improve the ability of the power system to ride through extreme events.
- **Ensure operational plans are in place** to manage increasingly common challenges that stem from a changing energy mix, including minimum electricity demand, lower levels of synchronous generation, and new ways to optimise ancillary services to maintain system strength and security.

2. Energy system and market insights

We publish statutory publications, reports and energy and market intelligence to the satisfaction of our stakeholders.

- **Deliver quality, timely reports and publications** that are valuable to AEMO stakeholders.

3. System and market technologies

We leverage technological innovations, uplift systems and invest in advanced analytics and forecasting capabilities to improve the efficient and secure operation of energy systems and markets.

Significant investment is being made to better deliver system performance at a reduced cost.

- **Upgrade and/or replace legacy grid and market IT systems** with more intelligent and scalable technology that meets the evolving demands of the industry.
- **Enhance our forecasting and real-time operations capabilities** to streamline control room decision-making processes. New technologies will provide access to timely and accurate data, advanced analytics and workflow-driven visualisations and forecast through a common platform.
- **Ensure enhancements to IT systems and procedures can manage the energy system** at lower levels of demand, synchronous generation dispatch and increasing levels of variability (including improved forecasting).

4. Cyber security

We work with government and industry to safeguard AEMO's and Australia's energy systems and data from malicious intent and intrusion.

- **Mature our cyber security capability** by enhancing our monitoring and detection of malicous activities through automated tools and Security Operations centre and enhancing our threat response by upgrading system recovery and back up options.
- **Actively engage with governments and industry to strengthen cyber security** by supporting industry insights and readiness assessments regarding cyber threats and activities, providing input into Commonwealth Critical Infrastructure Systems of National Significance Legislation, and sharing cyber information with members.

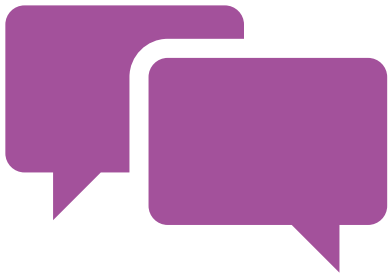
A Critical Decade of Change

Australia is experiencing the world's fastest and most profound power system transformation.

The '4 x Ds' of **decarbonisation**, **digitisation**, **democratisation** and **decentralisation** are directly impacting the system, accelerated by a complex range of societal, technological, economic and commercial shifts.

In recognition of the sheer pace and scale of change now confronting Australia's power systems, EF notes:

"Traditional, legacy approaches will need to be maintained in the near term, but inherent structural limitations will eventually constrain the pace of transition. Parallel to this, it is critical that designing a step change in power system capability starts today"



Daniel Westerman, AEMO's CEO

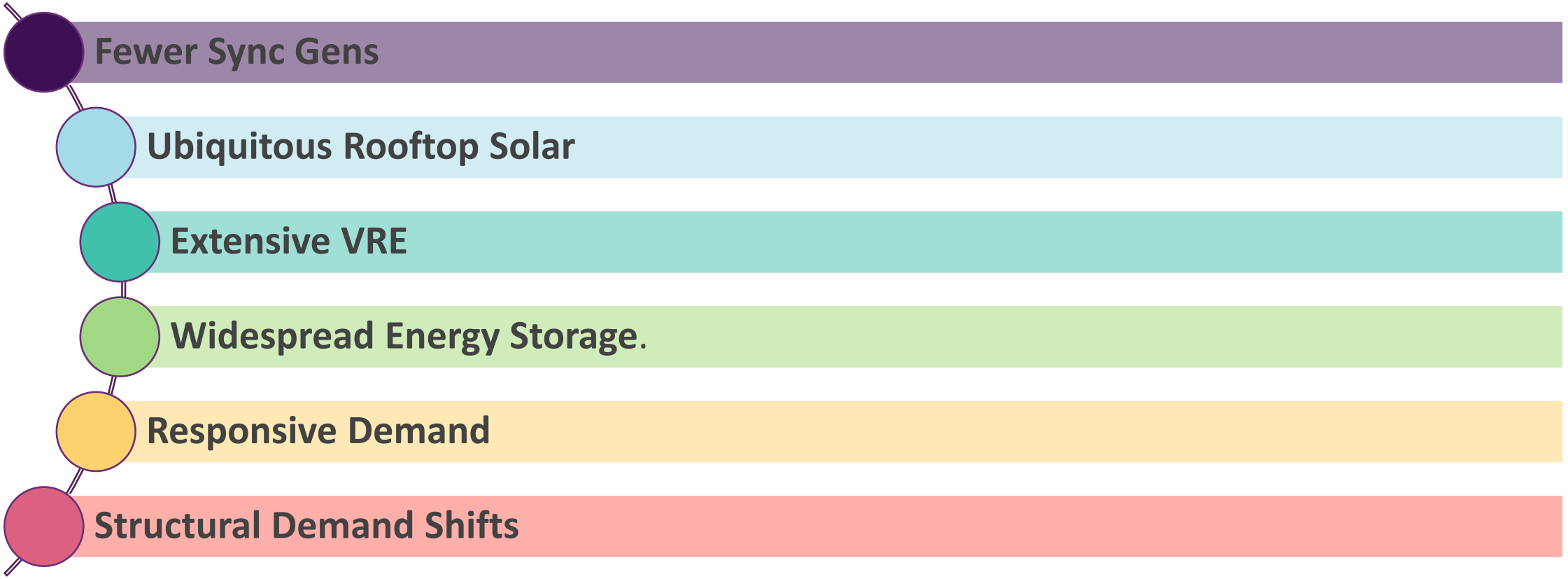
"It is a stunning democratisation of power."

"It's a transformation: turning historically passive electricity consumers into active generators."

"And a capital transfer, too. Power infrastructure investment decisions that were once the preserve of our nation's boardrooms are now being made around the kitchen tables in our towns and suburbs."

How the Operational Need is Changing

Engineering Framework Operational Conditions



The six identified future operational conditions from AEMO Engineering Framework, https://aemo.com.au/-/media/files/initiatives/engineering-framework/2021/nem-engineering-framework-initial-roadmap.pdf?la=en&hash=258E0F1A2E8E6EE6C00437E75BB170FF

Control Room of the Future (CROF)

Vision Statement

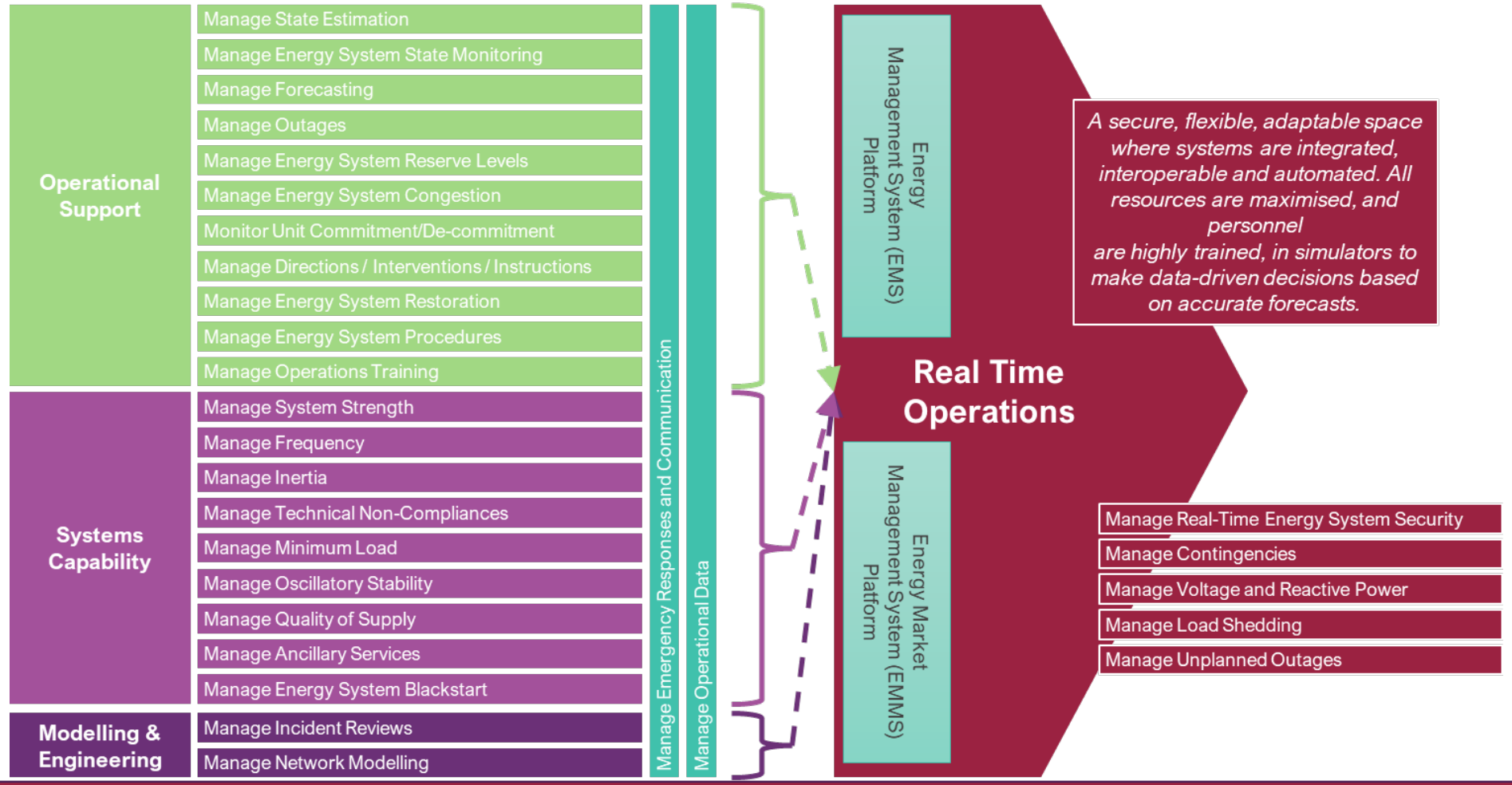
"A secure, flexible, adaptable, space where systems are integrated, interoperable and automated. All resources are maximised, and personnel are highly trained, in simulators to make data-driven decisions based on accurate forecasts."

Purpose

Secure, reliable, resilient, safe and flexible operations, which facilitate a goal of 100% renewable operation

Control Room of the Future (CROF)

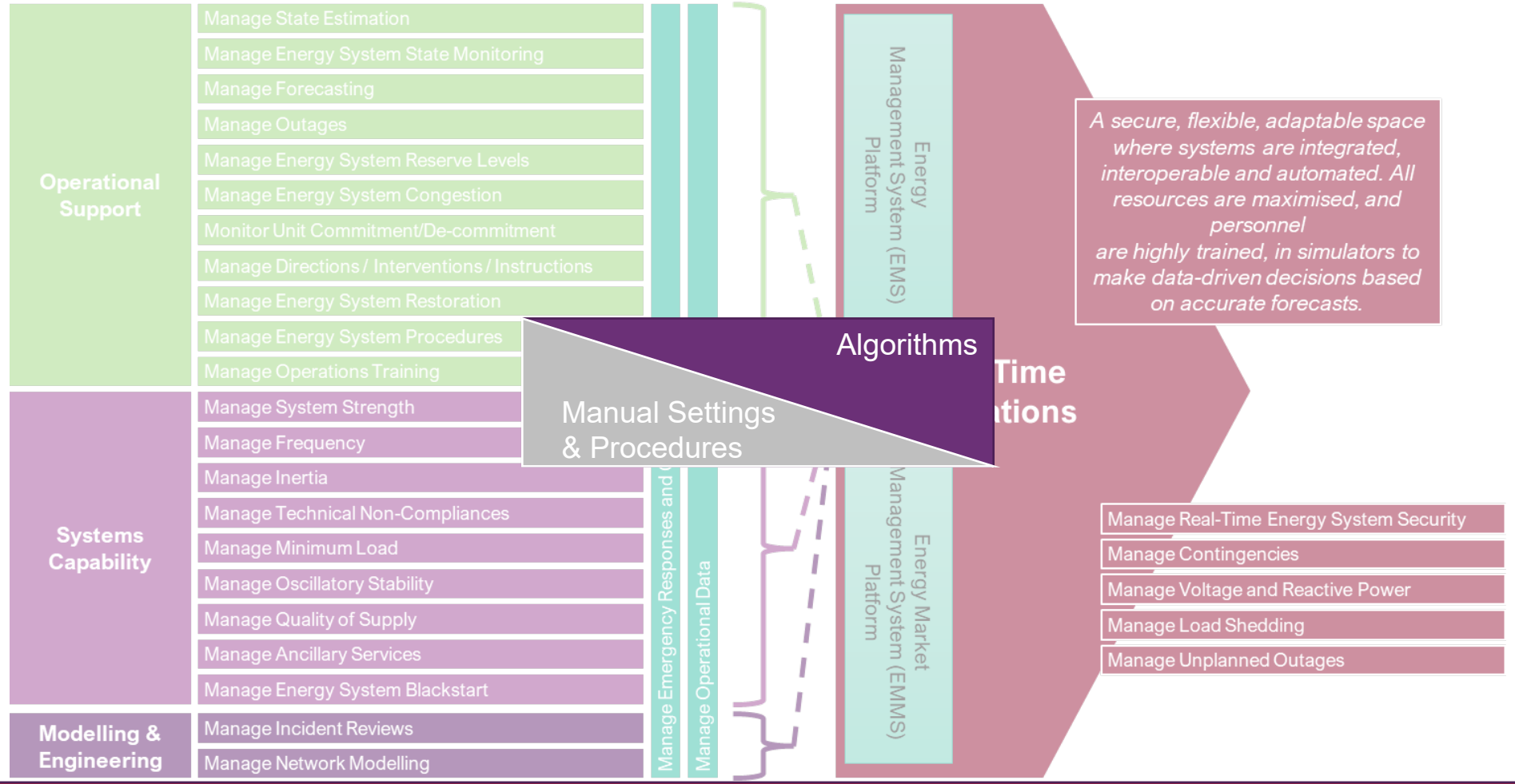
Secure, reliable, resilient, safe and flexible operations, which facilitate a goal of 100% renewable operation



Aligning our Capabilities to an integrated Future Mode of Operation

Control Room of the Future (CROF)

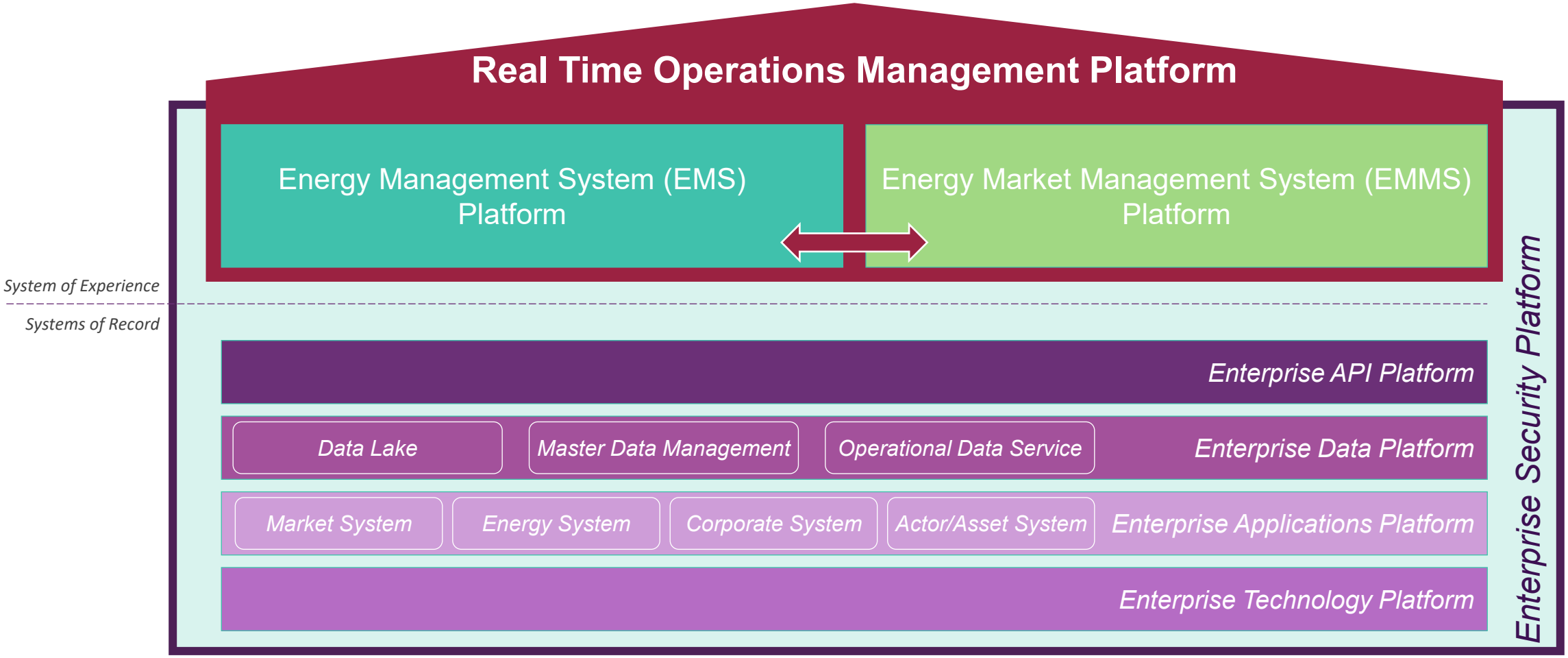
Secure, reliable, resilient, safe and flexible operations, which facilitate a goal of 100% renewable operation



The trend over time must be a reduction in manual activities as we increase our use of algorithms and automation

Real Time Operations Management Platform

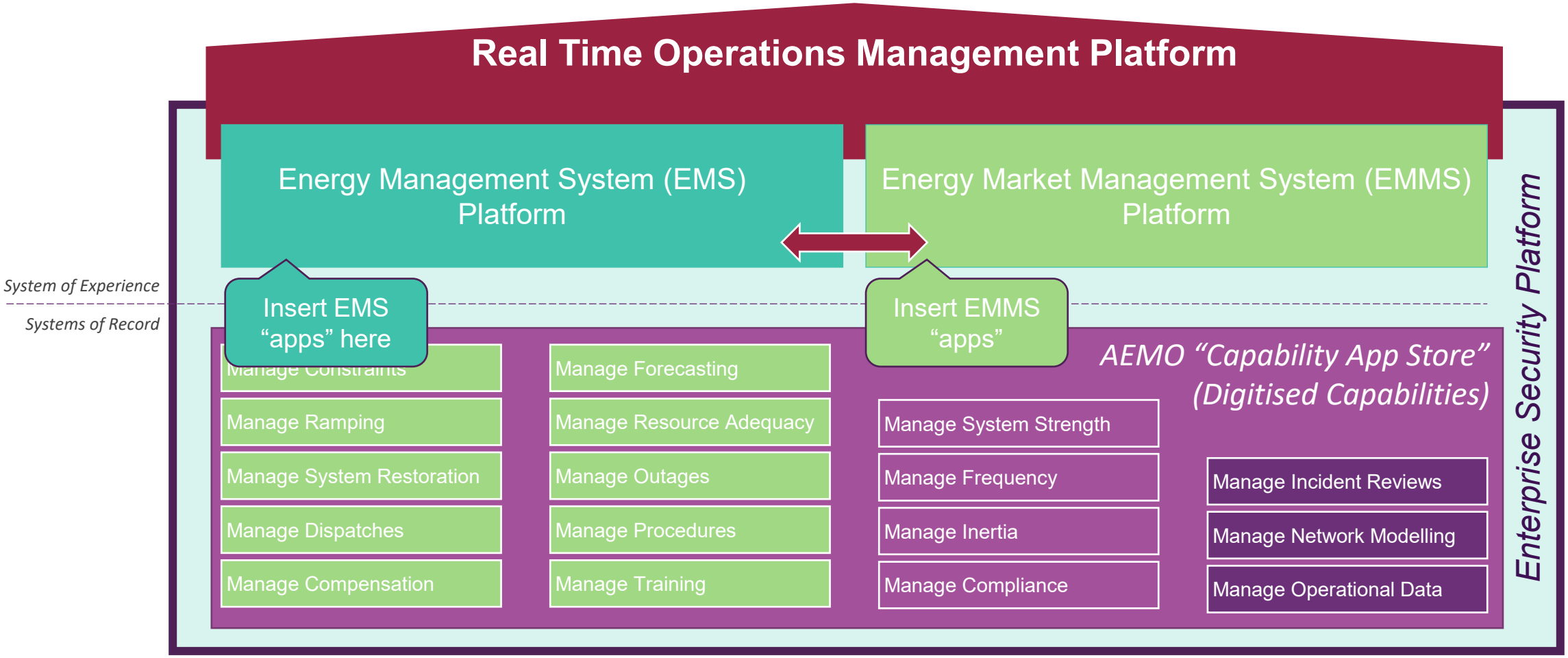
Conceptual Design



Aligning with Digital, we can quickly bring the vision to life based on the work products developed in the Operations Decision Making Tools project.

Real Time Operations Management Platform

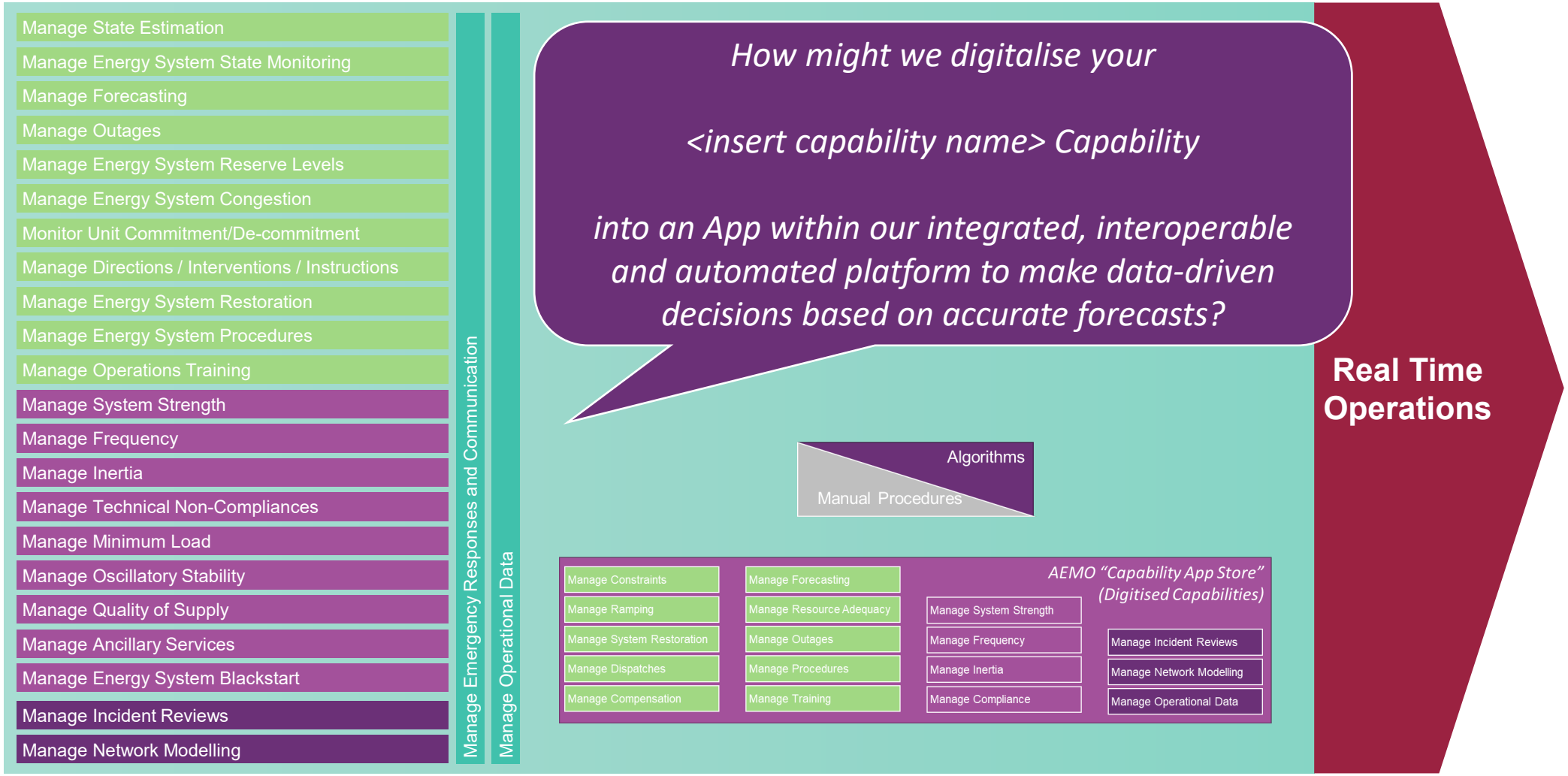
Conceptual Design



How might we digitalise critical capabilities and serve that into the Real Time Operations Management Platform. Working together, we are in the process of determining which capabilities are the most important.

Operations Technology Program

Capability Transformation Objective



Operations Technology Program

FY23/24 Major Projects

Manage Real-Time Energy System Security	Manage Forecasting	Manage Energy System Reserve Levels	Manage Oscillatory Stability	Manage Network Modelling
RTO Management Platform - User Interface / Dashboard - APIs - Market Notices - Constraints - Directions - etc	**Forecasting Platform**	**ST-PASA Replacement**	**PMU Monitoring Platform**	**Power System Modelling Uplift**

Operational Data Management Platform

- Enterprise Data Model
- Enterprise Data Platform (Enterprise Data Service, Operational Data Service, Data Science Virtual Machine, Master Data Management)
- Data Ownership
- Data Governance

Manage Operational Data

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Australian Energy Market Operator

NEMOC

National Electricity Market Operations Committee (NEMOC) Market Audit briefing

27 April 2023

pwc

Contents

1. Background and context

Background and purpose of today's discussion

- AEMO is required under the National Electricity Rules (NER) to appoint a market auditor to carry out reviews of such matters as AEMO considers appropriate, which must include:
  - the calculations and allocations performed by the metering system and settlements system;
  - the billing and information systems;
  - the scheduling and dispatch processes;
  - the processes for software management;
  - the AEMO procedures and their compliance with the NER.

- As a result, PwC were engaged to perform a limited assurance review of certain control procedures maintained by AEMO for the year ended 30 June 2022, providing limited assurance that control procedures are designed and operating effectively. Further information regarding the scope of the market audit is available here.

- Our primary responsibility was to deliver a review which fulfilled our obligations to AEMO's Finance, Risk and Audit Committee (FRAC). Our report to the AEMO FRAC outlined the FY22 Market Audit scope and approach, and the summary of material identified compliance risks and process taken by management to address these.

- As requested by AEMO we have summarised for participants in this document the results of our findings.

- Additionally, as we commence the FY23 market audit, we would value the opportunity to hear from participants any key areas of heightened risk so that we can consider them as part of our procedures.

2. FY22 Results

Summary of qualifications for the period 1 July 2021 to 30 June 2022

There were no findings for the period 1 July 2021 to 30 June 2022 which were reported as a qualification to the National Electricity Market Review Statements. We have considered materiality when determining the nature, timing and extent of our procedures and evaluating the impact of identified control weaknesses on our conclusion. Materiality is considered in the context of AEMO's objectives relevant to the area of activity being examined including qualitative and quantitative factors.

Summary of the NEM findings

There were no high or critical rated findings reported in FY22.

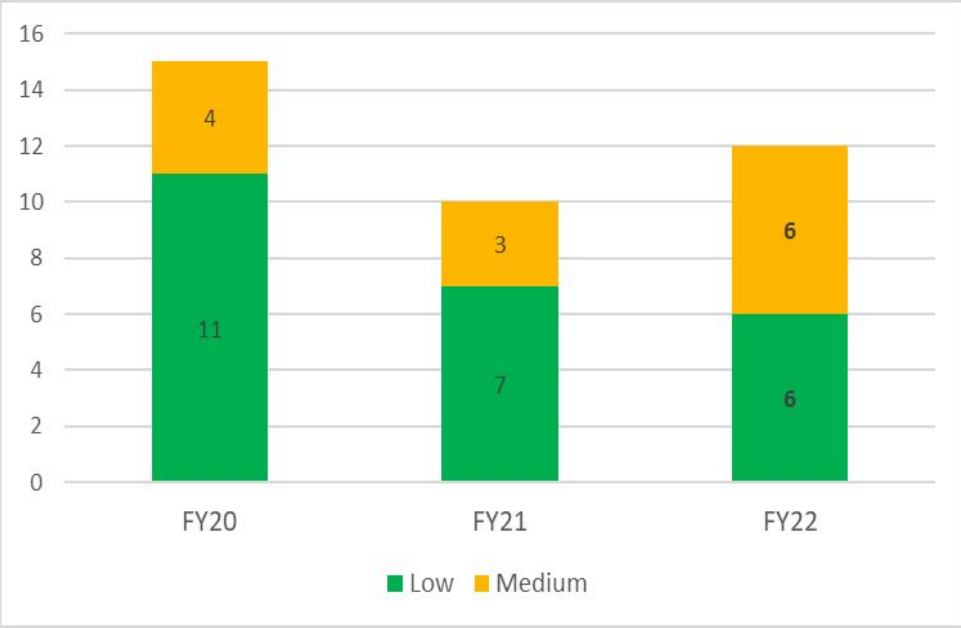
There were **twelve (12)** reported findings for FY22, of which:

- two (2) were PwC reported control observations
- ten (10) were AEMO Management reported non-compliances:

Of the twelve (12), six (6) were 'low' rated and six (6) were 'medium' rated.

Refer to the next page of this report for further details.

Based on the findings in the prior three years, the control environment remained stable year on year, with no high or critical rating findings reported.



2. FY22 Results

Overall Results

Twelve (12) new findings (shown beside) were reported either through management's self-assessment process or PwC independent testing during FY22. Six (6) of these were 'low' rated and six (6) were 'medium' rated. No high rated findings were identified.

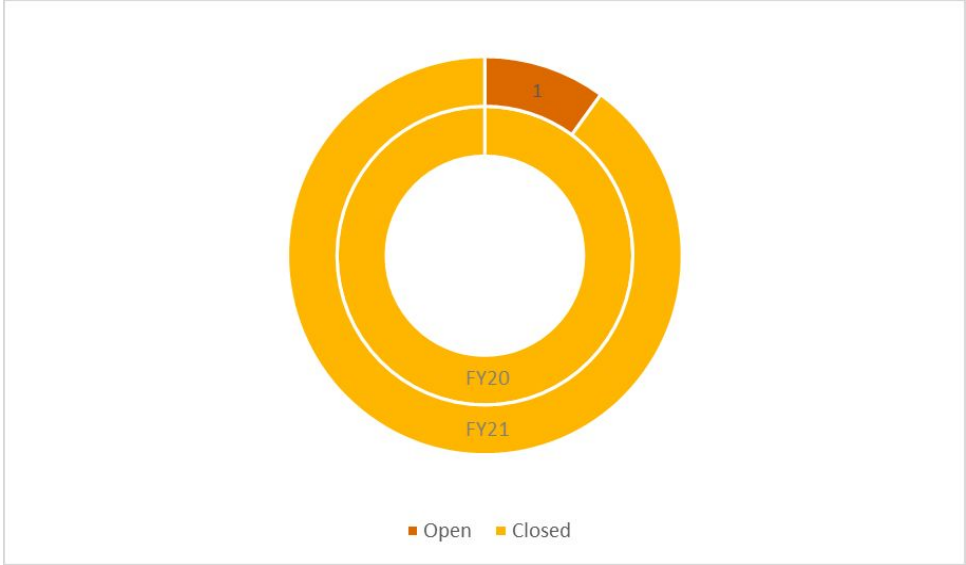
The 'medium' findings related to:

- updating Wholesale Demand Response processes following year 1 implementation
- improving processes for preventing data loss
- documenting control procedures for market suspensions
- isolated and subsequently corrected errors related to specific dispatch intervals and settlements statement.

In addition to this, twelve (12) Information Technology findings were reported in FY22, five (5) low rated and seven (7) medium rated.

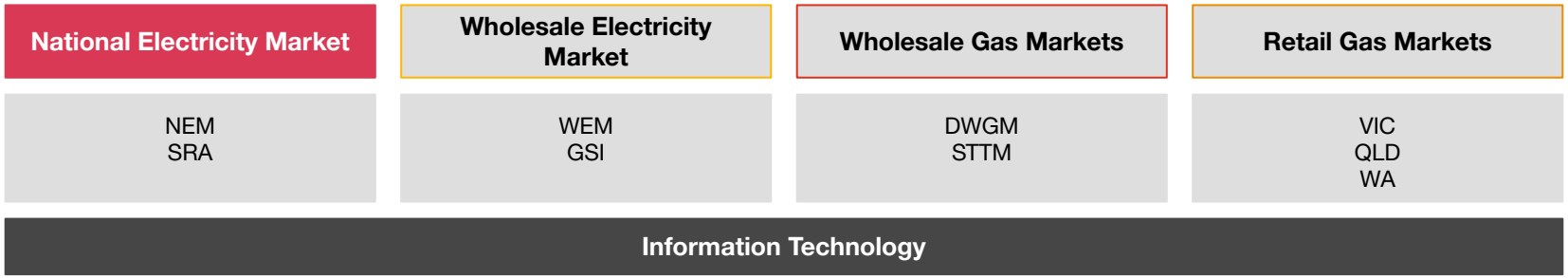
Closure of prior period findings

Good progress has been made in closing prior period findings, with **nine (9)** of the ten (10) prior year (FY21) findings closed during FY22 and all **twelve (12)** findings reported in FY20 now closed. The one open FY21 finding was within the settlements and prudentials process.



3. FY23 Approach

PwC has been engaged to review the control procedures maintained by AEMO for the year ended 30 June 2023. Our primary responsibility is to deliver a review which fulfils our obligations to AEMO's FRAC, AEMO Management and Market Participants. Our review will be undertaken for the following markets:



National Electricity Market

The objective of the National Electricity Market (NEM) audit is to form a conclusion as to whether anything has come to our attention that AEMO did not maintain, in all material respects, effective control procedures for the NEM for the year ending 30 June 2023.

Our review will cover:

- the calculations and allocations performed by the metering system and settlements system;
- the billing and information systems;
- the scheduling and dispatch processes;
- the processes for software management.

In FY23 we will also understand AEMO's compliance with the Settlement Residue Auction (SRA) Rules, which will include:

- the AEMO procedures and their compliance with the National Electricity Rules.
- AEMO's processes in identifying and contracting with eligible persons;
- SRA bidding, allocation and settlement processes in accordance with SRA procedures; and
- SRA system changes based on AEMO's change management process.

Information Technology

The scope of work includes IT General Controls supporting each Market, focusing on compliance with AEMO Information Technology policies and procedures in the areas of:

- Change Management
- Access to programs and data (including physical security, network security, environmental security and logical access management)
- Computer Operations (including backups and recovery, disaster recovery planning, batch processing).

Our procedures will consider the following activities:

- Review of non-compliances reported by AEMO management
- Follow up of implementation status of prior period actions
- Understanding design effectiveness of certain control procedures, including changes or developments since out last assessment
- Risk-based sample testing and data analysis to understand the operating effective of key controls for the period 1 July 2022 to 30 June 2023

4. Next Steps

Further areas of focus or comments?

Provide comment now

Email to AEMO:
supporthub@aemo.com.au

Contact PwC

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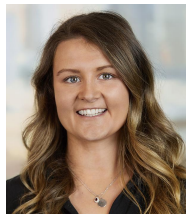

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Thank you

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