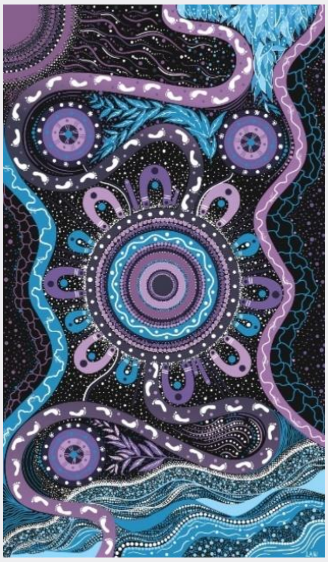
AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

AEMO Research Priorities

March 2025

Strategic research topics AEMO is interested in progressing with the research community



We acknowledge the Traditional Custodians of the land, seas and waters across Australia. We honour the wisdom of Aboriginal and Torres Strait Islander Elders past and present and embrace future generations.

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

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

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

Important notice

Purpose

This document outlines several priority research topics that AEMO is interested in progressing through engagement with the research community.

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1 Purpose of this document

This document outlines priority research topics that AEMO has identified as aligning with our strategic priority of Navigating the Energy Future[1]. AEMO is interested in progressing these topics in collaboration with the research community to develop solutions which will support AEMO's vision to enable net zero.

This document will be periodically updated as AEMO's research priorities evolve.

2 How to engage

Parties interested in collaborating on one or more of AEMO's identified research priorities, or who want further information about research collaborations with AEMO, including discussions on other potential research topics that parties believe are aligned with AEMO's objectives, please contact AEMO by emailing us at research@aemo.com.au.

3 Context

AEMO's research interests span a wide range of areas related to the operation of electricity and gas systems and markets, from immediate practical challenges of secure system operation with high penetration of renewables to fundamental research questions and longer-term challenges in enabling a net zero energy system.

The significant investment landscape for energy research in Australia and globally has the potential to assist Australia's energy transition and AEMO's role within it.

AEMO has a long history of collaborating with the Australian research community, including several active projects with CSIRO and Australian and international universities. We believe that enhancing our research partnerships will deliver more opportunities to assist our efforts to navigate the energy future, one of AEMO's four strategic priorities.

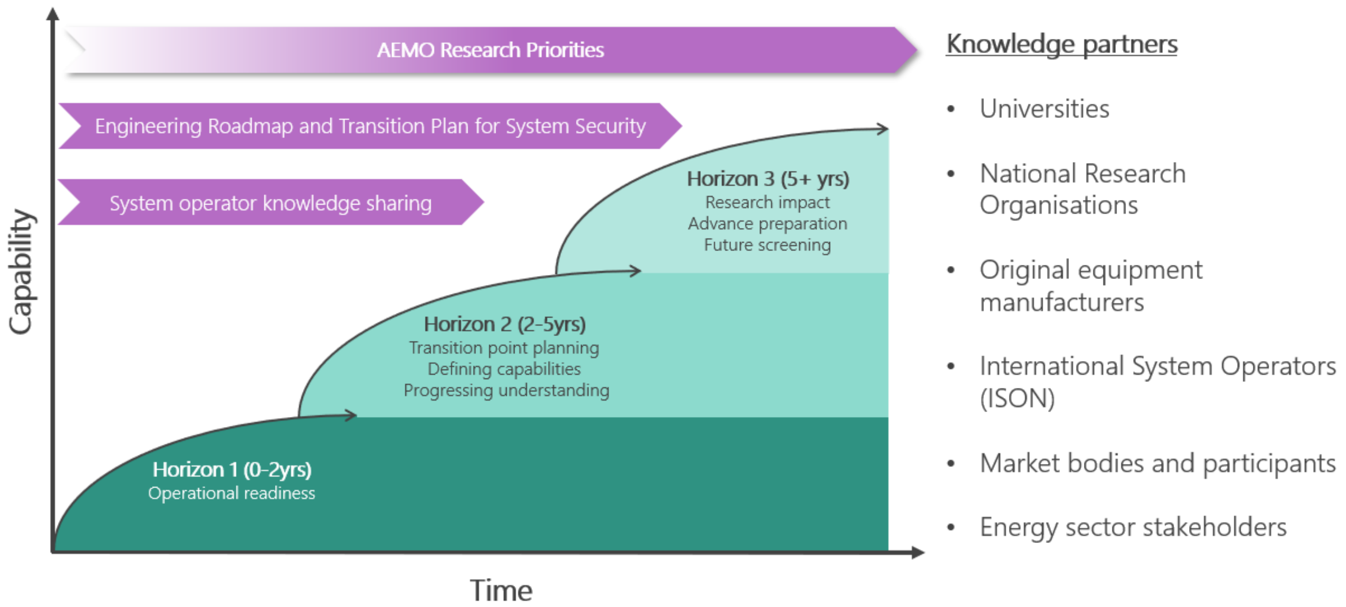
The research priorities detailed in this document reflect AEMO's current view of strategic emerging research opportunities. These are areas in which AEMO is already actively working, but where there are additional exploratory questions to be unpacked, and AEMO sees longer-term strategic value could be added through collaboration with the research community. The content and structure of these areas of interest is expected to evolve over time as AEMO's understanding of system needs grows and as research capabilities advance informed by ongoing engagement across the broader energy sector. AEMO welcomes feedback on future avenues for engagement.

[1] https://aemo.com.au/-/media/files/about_aemo/corporate-plan/2024/aemo-strategic-corporate-plan-fy25.pdf

These research priorities are closely aligned with other AEMO strategic initiatives, including:

- AEMO's National Electricity Market (NEM) and South West Interconnected System (SWIS) Engineering Roadmaps[2] and Transition Plan for System Security [3].
- AEMO's collaboration with the International System Operators Network (ISON), including shared system operator priorities to support the transition to high renewable power systems[4].

Figure 1 AEMO knowledge-building activities spanning three time-horizons



The Engineering Roadmaps and *Transition Plan for System Security* are the primary vehicles for prioritising AEMO's effort in the near and medium term. They identify and prioritise the critical engineering actions required to advance operational capability of Australia's largest power systems to securely operate at times of high renewables contribution. They target operational readiness efforts over the next two years, and also the critical activities AEMO is addressing to support system operation 2-10 years ahead.

AEMO's research initiative builds on this work to help crystallise research efforts on questions that AEMO sees as important to tackle now, so they may be resolved to support future system operation.

In developing these research priorities, AEMO identified a wide array of topics that may be of interest to AEMO. This longlist was then prioritised to focus on a shortlist of research topics AEMO would like to see progressed in the first instance. These are areas where AEMO is willing to commit initial effort to progress these questions in partnership, where we would not be able to materially progress on our own, and we consider them to be of high value to the longer-term energy transition.

[2] https://aemo.com.au/initiatives/major-programs/engineering-roadmap

[3] https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/transition-planning/aemo-2024-transition-plan-for-system-security.pdf

[4] https://aemo.com.au/-/media/files/about_aemo/international-system-operator-collaboration/system-operator-priorities-report-2025.pdf

4 Research priorities

1. **Modelling major inverter-based loads (IBLs) and their performance in weak grid conditions.**
2. **Analysis and quantification of grid-forming (GFM) inverter capability to provide power system requirements.**
3. **Electromagnetic transient (EMT) and impedance scan tools and methodologies for planning, connections, and operational studies with an increasing share of inverter-based resources (IBR).**
4. **Coordinated storage from consumer energy resources (CER).**
5. **Management of energy in grids with high penetration of battery energy storage systems (BESS).**

4.1 Modelling major inverter-based loads (IBLs) and their performance in weak grid conditions

The rapid growth in the development of IBLs, such as hydrogen electrolysers, data centres and electric vehicles (EVs), presents both opportunities and challenges for power system planners and operators. These IBLs could offer flexible energy consumption, which, if properly managed, could optimise the use of existing transmission and distribution infrastructure, deferring investment and reducing cost. However, IBLs are interfaced with the grid through power electronics, making them more susceptible to control system instability, especially in weak grid conditions, with potential for undesirable interactions and performance issues.

Defining the appropriate modelling scope for IBLs is challenging due to the complex composition of load facilities, various protection systems, the lack of historical modelling requirements and original equipment manufacturer (OEM) support. It is crucial to balance the need for detailed modelling information with the time and effort required to obtain it.

Objective: Develop fit-for-purpose models of IBLs to represent their flexibilities and vulnerabilities

This process may evolve iteratively as the modelling requirements for IBLs develop over time, therefore proper process management may be needed to identify opportunities for future modelling requirements update.

AEMO is interested in exploring:

- What state-of-the-art modelling practices are utilised by other system operators and research institutions?
- What potential vulnerabilities or instability mechanisms are associated with IBLs?
- What is the availability of case-specific approaches to IBL-modelling based on different risks and technologies?
- How can a reasonable approach to determine the modelling scope be developed? What components should be included for models of different IBL facilities, including control systems and protection systems?
- How can fit-for-purpose model aggregation approaches be developed, considering the complexity of IBL facilities with different load (and non-IBL) components?

4.2 Analysis and quantification of grid-forming (GFM) inverter capability to provide power system requirements

With increasing penetration of IBR and retirement of synchronous generators in power grids worldwide, new operational challenges need to be considered by power system operators, including for system strength, voltage and frequency control, synchronous inertia, and power system protection. GFM inverters have the potential capability to address some of the operational challenges associated with high levels of IBR penetration. GFMs are increasingly being deployed globally due to their unique capabilities compared to traditional grid-following inverters (GFLs). Unlike GFLs, GFMs create their own voltage waveform and have the potential to provide synthetic inertia, provide voltage support, and improve voltage stability. With specific design, GFMs can also provide black start capability.

Objective: Analysis and quantification of GFM inverter capabilities to provide inertia and system strength

It is crucial to determine the most appropriate assessment approach when quantifying the delivery of certain capability from GFMs, considering different GFM architecture, and whether the same assessment approach can be applied equally to rotating machines and IBR, both of which would likely to be included in the future power system.

In addition, the assessment and quantification should target fulfilling power system requirements to ensure stable operation of the power system with a high share of IBR.

AEMO is interested in exploring:

- How do different control system architectures and designs influence inertia delivery to power system by GFM inverters?
- What is the most appropriate quantification method for assessing the amount of inertia provided by a specific GFM inverter, and how applicable is this method for quantifying synchronous machine inertia delivery?
- Are there technical justifications for treating GFM inverter inertia differently from synchronous machine inertia? What is the most appropriate inertia quantification framework considering future power systems with both GFM inverters and synchronous machine presence?
- Can inertia-assessment frameworks be extended to other power system requirements, such as system strength provision, voltage, and frequency control requirements?

4.3 Electromagnetic transient (EMT) and impedance scan tools and methodologies for planning, connections, and operational studies with an increasing share of inverter-based resources (IBR)

The increasing share of IBR in power systems necessitates advanced tools and methodologies for planning, connections, and operational studies. Frequent instances of control interactions are being observed by system operators, both in power system simulations and real-time operation.

Currently, the majority of system operators rely on EMT simulation to understand changing power system dynamics associated with an IBR-rich grid. Some system operators and researchers are exploring the use of frequency scan techniques such as impedance scans to better understand these phenomena, since each method investigates a different aspect of power system security. However, both methods require detailed simulation models, high-end computation hardware, and extensive simulation time.

Objective: Integrate these two time-intensive analysis approaches in a cost-effective manner and inform system-operator activities including verifying planning criteria, conducting generator connection assessments, and investigating operational risks and incidents

AEMO is interested in exploring:

- What are appropriate study methodologies for EMT and impedance scan tools?
- What screening methods can be applied to optimise the needs of time-consuming simulations, while providing necessary levels of quality and accuracy of results?
- What are efficient methods to systematically review and cross-reference results produced by different study methodologies?

4.4 Coordination of storage from consumer energy resources (CER)

Under the *Step Change* scenario of AEMO's 2024 *Integrated System Plan*, "Coordinated CER storage" from resources such as batteries and EVs is forecast to reach approximately 50% of dispatchable capacity by 2050. However, AEMO's draft 2025 *Inputs, Assumptions and Scenarios Report*[5] suggests that the level of CER coordination will be lower than previously projected. This highlights the uncertainty in this category.

AEMO seeks to test the robustness of these forecasts and continue to refine them. As a nascent field, it is currently difficult to forecast future growth based on historical trends.

Objective: Develop, expand, and refine forecasts of coordinated CER, including for non-storage coordinated CER

AEMO is interested in exploring:

- Taxonomies of concepts/technologies that contribute to coordinated CER, helping to support a fulsome/accurate comparison of forecasts from various sources.
- Methods to forecast the growth in each category of coordinated CER within the above taxonomies. It is anticipated that this will require methods to:
  - monitor the development of new customer offerings, including the extent of market participation within those offerings,
  - account for expected technological and regulatory changes,
  - forecast prices for batteries and other flexible CER,
  - forecast changes in market dynamics, including network support opportunities and constraints, that drive financial value propositions, and
  - forecast developments in consumer preferences, which influence the contribution of financial and non-financial drivers of take-up.

[5] https://aemo.com.au/consultations/current-and-closed-consultations/2025-iasr

4.5 Management of energy in grids with high penetration of battery energy storage systems (BESS)

The transition of Australian electricity grids, from predominantly conventional generation to grids with high penetrations of variable renewable energy (VRE), firmed by storage (including BESS) and supported by gas, means that the operation of storage systems such as BESS will be critical to the secure and reliable operation of the network.

Current dispatch and Projected Assessment of System Adequacy (PASA) tools do not fully address the management of short (intraday) and medium-term duration BESS (multiple days), particularly in periods where there are energy shortfalls (for example, during Dunkleflaute) or when demand is exceptionally high

Objective: Review the capability existing operational tools to take advantage of energy limited plant such as BESS

AEMO is interested in exploring:

- The ability of existing short-term planning and control room tools to optimise the dispatch of BESS and manage energy on an inter-temporal basis.
- The detail of any existing gaps or shortcomings, including in the light of forecast changes in assets.
- Recommendations for addressing any current or future shortcomings or issues.