Engineering Roadmap: insights on future power system security and grid-forming inverters

Please note that this webinar will be recorded and published on our website.

17 September 2026 | 90 minutes

Public

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 delivered 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.

Read our RAP

Today’s agenda

Item	Speaker	Timing
Welcome and context	Mariela Mendoza	45 min
Engineering Roadmap close-out	Senah Javed	
Engineering Roadmap evolution and its future	Chris Mock	
Insight 1: IBRs and protection quality fault current	Andrew Halley	
Insight 2: Firming up the role of GFM BESS to support network protection	Andrew Halley	
Insight 3: Quantifying system strength support	Jingwei Lu	
Insight 4: Future damping trends	Jingwei Lu	
What to expect for the rest of 2026	Senah Javed	
Q&A	**Panel**	**45 min**

Public

How to interact today – Q&A

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Engineering Roadmap - FY2026 close-out and its future

Presenters – Senah Javed & Chris Mock

Engineering Roadmap FY26 Close-Out

AEMO

Uplift Operational Capabilities

- PV Non-Scheduled Generator (PVNSG) generation forecasting — FY26_01
- Enable real-time visibility of load allocation to the Under Frequency Load Shedding (UFLS) scheme — FY26_02
- Uplift in NEM short-term planning and outage management — FY26_03
- Operational System Restart consolidation including treatment of inverter-based resources — FY26_04
- Review of SWIS Load Contingency Limit — FY26_05
- Improvements to AEMO Power System Simulator for Engineering (PSSE) dynamic models — FY26_06
- Review of Rate of Change of Frequency safe limit — FY26_07
- Review of impacts on dispatch from charge state of multiple large batteries — FY26_08
- Operator training uplift across industry — FY26_09

Prepare for Transition Points

- Horizon 1 transition point planning and analysis — FY26_10
- Pathway to substituting synchronous capability in the SWIS — FY26_11
- Assess requirement and options for improving system strength in priority areas — FY26_12
- Improved capabilities to manage minimum system load — FY26_13
- Horizon 2 transition point planning and analysis — FY26_16
- Coal retirement assessment — FY26_17
- Horizon 3 analysis to identify system security issues and future investment requirements — FY26_26
- Investigate 100% IBR power system operation and requirements — FY26_27

Integrate CER

- Onboarding of dynamic operating envelope data — FY26_14
- DER data for power system analysis — FY26_18
- Improve quality of DER standing data — FY26_19
- CER/DER management during system restart — FY26_20
- Co-design operational coordination architecture and scope T-D coordination function — FY26_28

Enable New Technologies

- System strength beyond connection point — FY26_15
- Hybrid Plant Commissioning Fact Sheet — FY26_21
- Frequency scanning trials — FY26_22
- Analyse fault current performance from GFM — FY26_23
- Quantifying system strength support from GFM — FY26_24
- Inverter-based load modelling — FY26_25
- Early assessment framework – OEM trials — FY26_29

STATUS

- Complete
- Partially Complete

SCOPE

- NEM and SWIS delivery
- NEM delivery with SWIS relevance
- SWIS delivery with NEM relevance
- NEM only
- SWIS only

Engineering Roadmap Future

Established the foundations

2019 Integrating Utility-scale Renewables and Distributed Energy Resources in the SWIS

2020 Renewable Integration Study: Stage 1 Report (NEM)

2021 NEM Engineering Framework: Initial Roadmap

2021 Renewable Energy Integration – SWIS Update

2022 Engineering Roadmap to 100% Renewables (NEM)

2024 SWIS Engineering Roadmap

Delivered priority actions and Transition Planning

2022 Engineering Roadmap: FY2023 Priority Actions Report (NEM)

2023 Engineering Roadmap: FY2024 Priority Actions Report (NEM)

2024 Engineering Roadmap: FY2025 Priority Actions Report (NEM)

2024 Transition Plan for System Security (NEM)

2025 Engineering Roadmap: FY2026 Priority Actions Report (NEM and SWIS)

2025 Transition Plan for System Security (NEM)

2026 Engineering Roadmap to 100% Renewables: FY2026 Priority Actions Close-out Report (NEM and SWIS)

Integrated Transition Planning and more

2026 NEM Transition Plan for System Security
December 2026

Including 3-year Engineering Roadmap workplans

2027 NEM Transition Plan for System Security
December 2027

Including updated 3-year Eng Roadmap workplans

2027 Future SWIS reports
Timing and scope TBC

From late 2026, the Engineering Roadmap reporting will be integrated into Transition Planning for the NEM, with workplans refreshed on a rolling three-year horizon.

2026 Transition Plan for System Security

2025 – Merged TPSS and system security planning

2025 TPSS

Part A – Transition planning

Part B – Regional transition plans

Part C – System wide developments and plans

Evolving understanding of what is needed to maintain system security in a low- to zero- emissions system

Appendix 1 - Reliability Panel feedback on the 2024 TPSS
Appendix 2 - Transmission network requirements (NSCAS, System Strength and Inertia)
Appendix 3 – MSL Regional Assessments

Engineering Roadmap Priority Actions

Preparing Australia's power systems for operation at times of high renewables contribution.

2026 – Merging Engineering Roadmap into TPSS

2026 TPSS

Part A – Transition planning

How the energy transition affects system security. AEMO's approach to transition planning.

Condensed

Part B – Regional transition plans

Transition points in maintaining security over the coming 10+ years, integrating system security planning studies.

Updated transition points and transition point assessments

Part C – Engineering Roadmap

Workplans to evolve understanding of what is needed to maintain power system security in a low- or zero-emissions power system, and uplift capabilities.

Engineering Roadmap workplan overview, objectives for next 3 years

Appendix 1 - Reliability Panel feedback on the 2025 TPSS
Appendix 2 - Transmission network requirements (NSCAS, System Strength and Inertia)
MSL Appendix - TBC

Proposed Engineering Roadmap Power System Criteria prioritised for 2026 TPSS

NEM ER workplans developed with:

1. Rolling 3-year window
2. Connected to far future system state with future-back analysis

Initial proposal:

- 3 criteria chosen for detailed work plan development.
- Others informed by existing initiatives or BAU processes

ER focus: new detailed workplans

- System restoration
- System strength
- Transient and oscillatory stability

Activities from current initiatives

- Large Loads
- DER
- Operability

Managed by BAU processes

- Frequency and inertia
- Voltage control

Engineering Roadmap workplan template

Key

- AEMO Understanding
- Industry Understanding
- Trial
- AEMO Capabilities
- Industry Capabilities
- Reform

Eng Roadmap Workplan

Transition Points / Objective	H1 2026	H2 2026	H1 2027	H2 2027	H1 2028	H2 2028	H1 2029	H2 2029	Mid 2030s
					Transition Point 1	Transition Point 3	Transition Point 5	Transition Point 7	Credible scenario
					Transition Point 2	Transition Point 4	Transition Point 6	Transition Point 8	

Objective 1

Work package that builds understanding

Work package that lifts capabilities

Transition point deadline

Objective 2

Work package that builds understanding

Type 2 Transitional Service trial

Work package that lifts capabilities

Objective 3

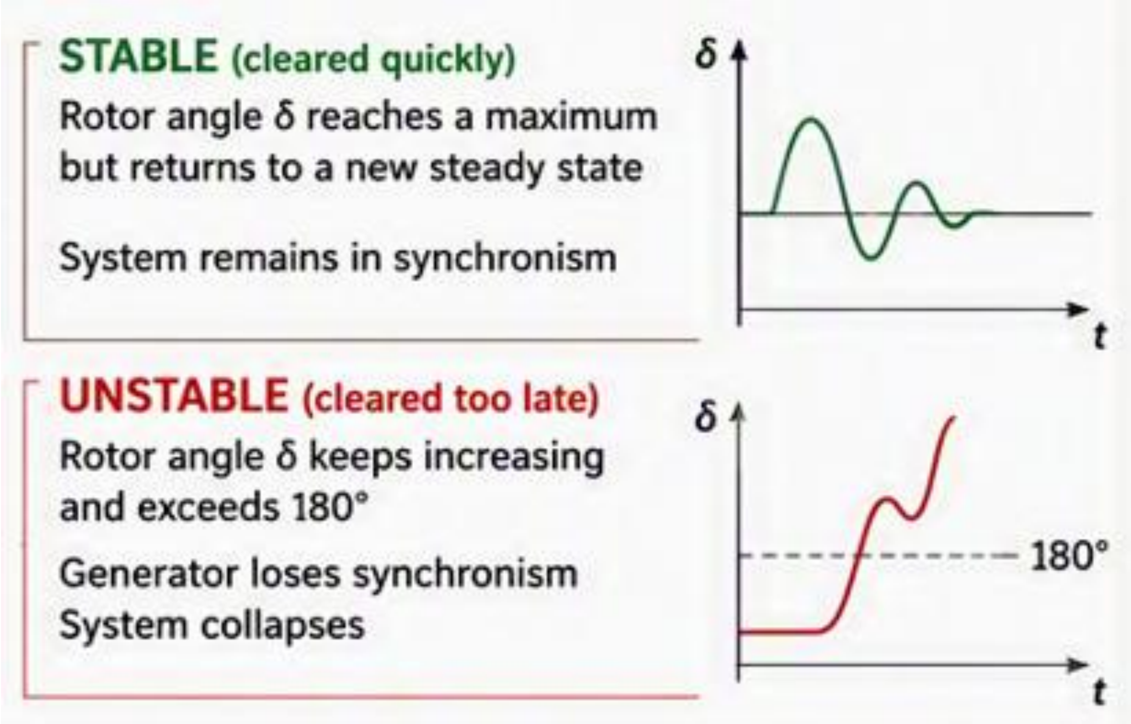
Steps to '100% RE'

IBRs and protection quality fault current

Insight #1 – Andrew Halley

Network protection challenges with increasing IBR

To set the scene… Protection matters!



An easy one to remember: (PPE)S – People, Plant, Environment and System

All images on this page have been AI generated.

What has AEMO been investigating?

Analysis efforts have so far focused on:

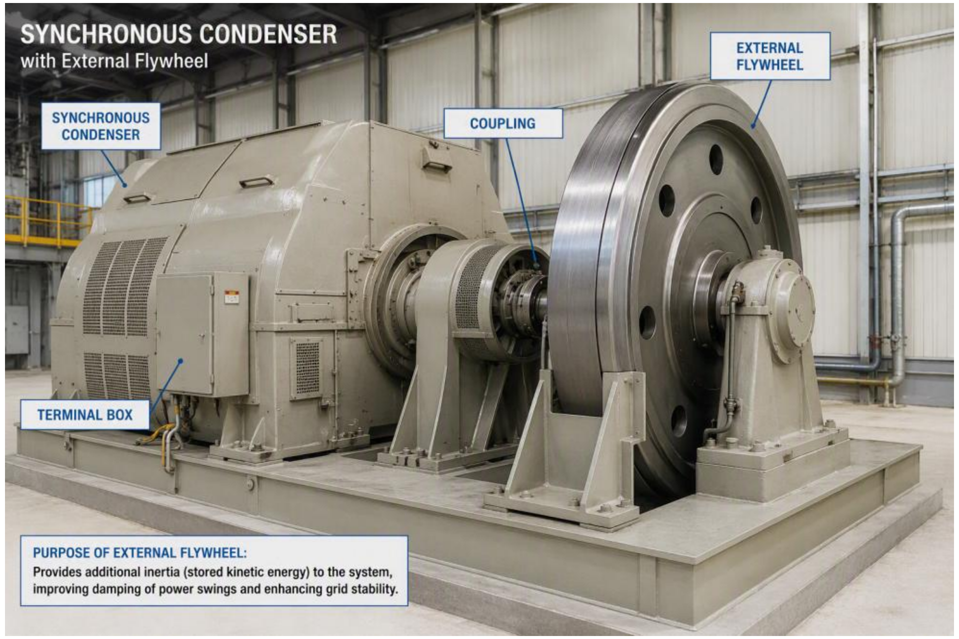
- Understanding how the fault current characteristics of IBR differ from synchronous machines.
- Investigating how any differences might impact the performance of existing network protection schemes - what are the risks?
- Focus has been given to understanding grid forming (GFM) converters used in battery energy storage system (BESS) applications.

Our target is to answer the question:

Can GFM BESS be used as a substitute for synchronous machines to help satisfy **minimum system strength requirements (NER Schedule 5.1a.9)?**

What is the driver?

Potential long-term benefits for the industry…



Syn-Con:

- Costs
- Delivery times

VS

BESS:

- GFM is now more common
- Storage is critical to future NEM.

Objective:

Maximise the system security benefits of GFM BESS and create alternative procurement options for system strength service providers (SSSPs).

All images on this page have been AI generated.

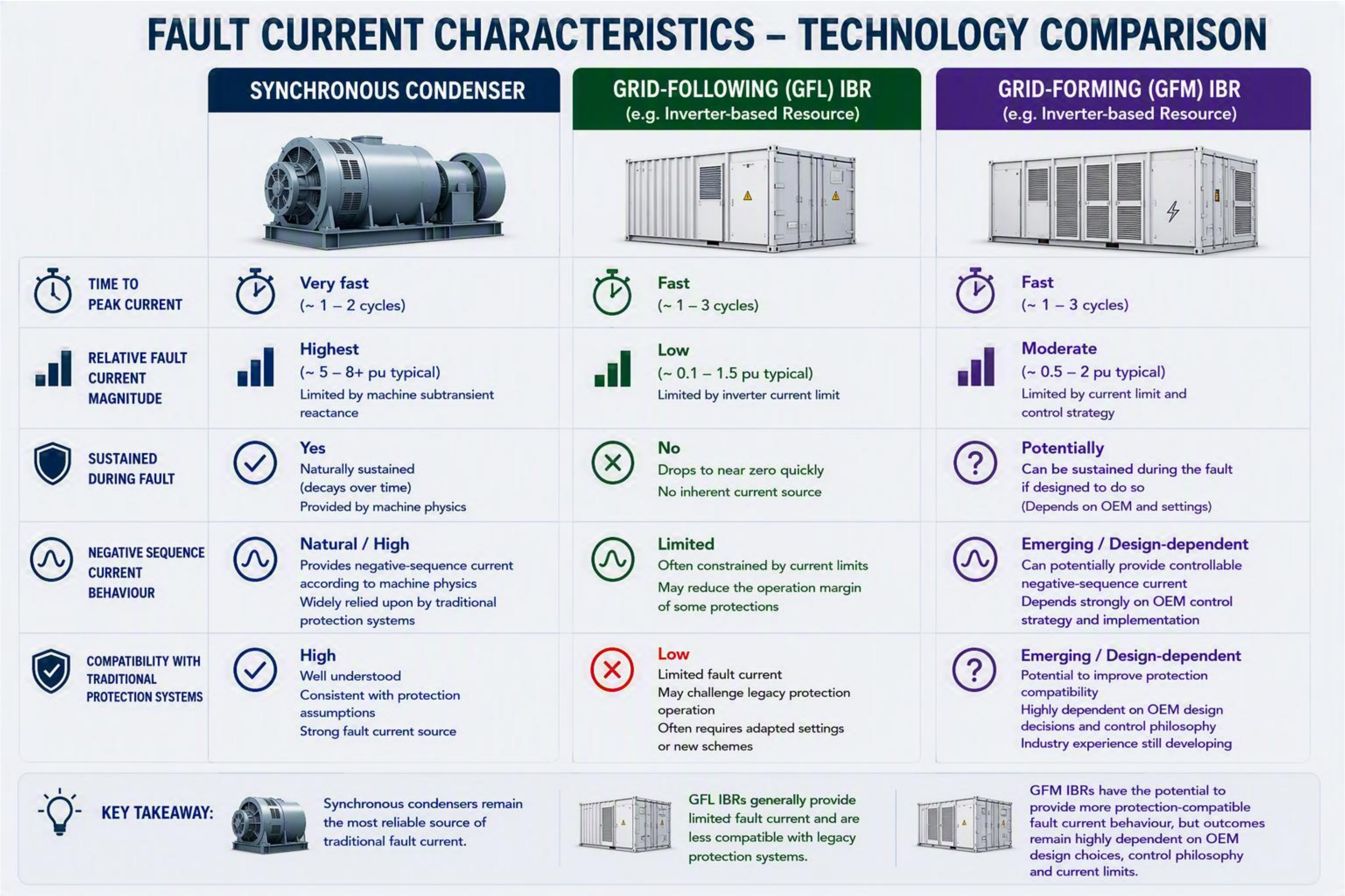
How have we been doing this?

- AEMO has engaged with reputable consultants to explore the fault response capabilities of IBR and protection related issues…
- Two desktop studies have been completed and published.

www.aemo.com.au/initiatives/major-programs/engineering-roadmap/engineering-roadmap-execution-reports

- Two more are on the way for publication in Q4 2026…

What has been established so far?



FAULT CURRENT CHARACTERISTICS – TECHNOLOGY COMPARISON

	SYNCHRONOUS CONDENSER	GRID-FOLLOWING (GFL) IBR (e.g. Inverter-based Resource)	GRID-FORMING (GFM) IBR (e.g. Inverter-based Resource)
TIME TO PEAK CURRENT	Very fast (~ 1 – 2 cycles)	Fast (~ 1 – 3 cycles)	Fast (~ 1 – 3 cycles)
RELATIVE FAULT CURRENT MAGNITUDE	Highest (~ 5 – 8+ pu typical) Limited by machine subtransient reactance	Low (~ 0.1 – 1.5 pu typical) Limited by inverter current limit	Moderate (~ 0.5 – 2 pu typical) Limited by current limit and control strategy
SUSTAINED DURING FAULT	Yes Naturally sustained (decays over time) Provided by machine physics	No Drops to near zero quickly No inherent current source	Potentially Can be sustained during the fault if designed to do so (Depends on OEM and settings)
NEGATIVE SEQUENCE CURRENT BEHAVIOUR	Natural / High Provides negative-sequence current according to machine physics Widely relied upon by traditional protection systems	Limited Often constrained by current limits May reduce the operation margin of some protections	Emerging / Design-dependent Can potentially provide controllable negative-sequence current Depends strongly on OEM control strategy and implementation
COMPATIBILITY WITH TRADITIONAL PROTECTION SYSTEMS	High Well understood Consistent with protection assumptions Strong fault current source	Low Limited fault current May challenge legacy protection operation Often requires adapted settings or new schemes	Emerging / Design-dependent Potential to improve protection compatibility Highly dependent on OEM design decisions and control philosophy Industry experience still developing
KEY TAKEAWAY:	Synchronous condensers remain the most reliable source of traditional fault current.	GFL IBRs generally provide limited fault current and are less compatible with legacy protection systems.	GFM IBRs have the potential to provide more protection-compatible fault current behaviour, but outcomes remain highly dependent on OEM design choices, control philosophy and current limits.

A. Existing network protection systems are designed around the fault current characteristics of synchronous machines rather than IBR.

B. GFM is still an **evolving technology** - OEM control strategies vary and can cause material differences when comparing fault current characteristics.

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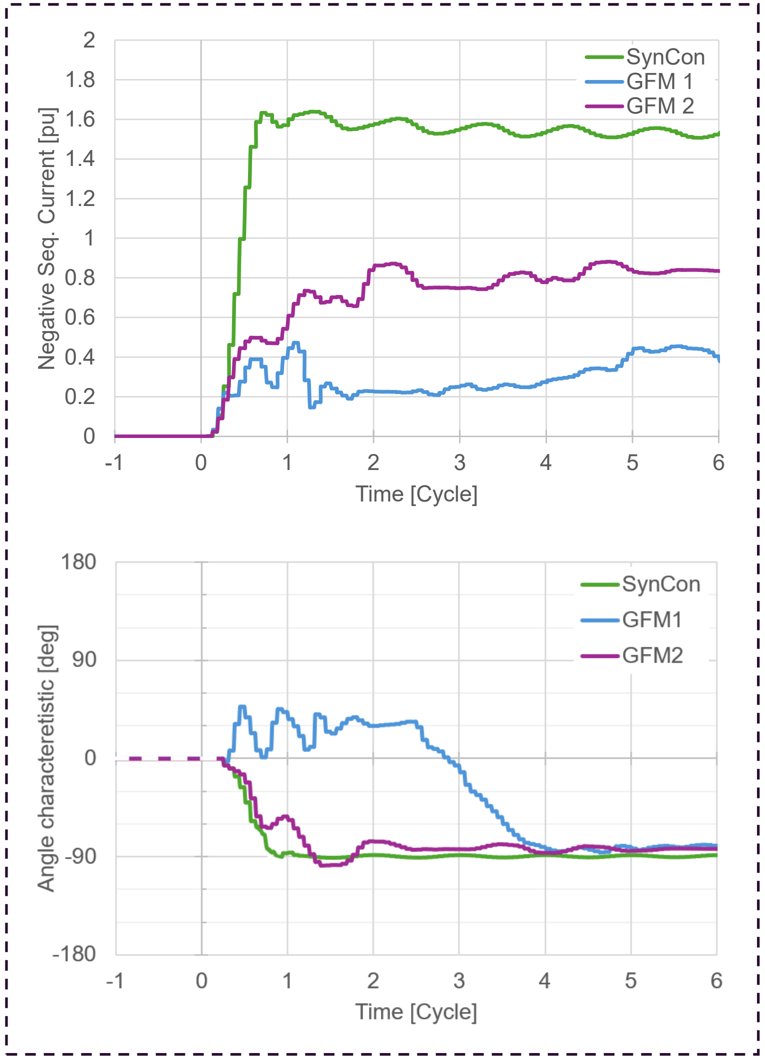
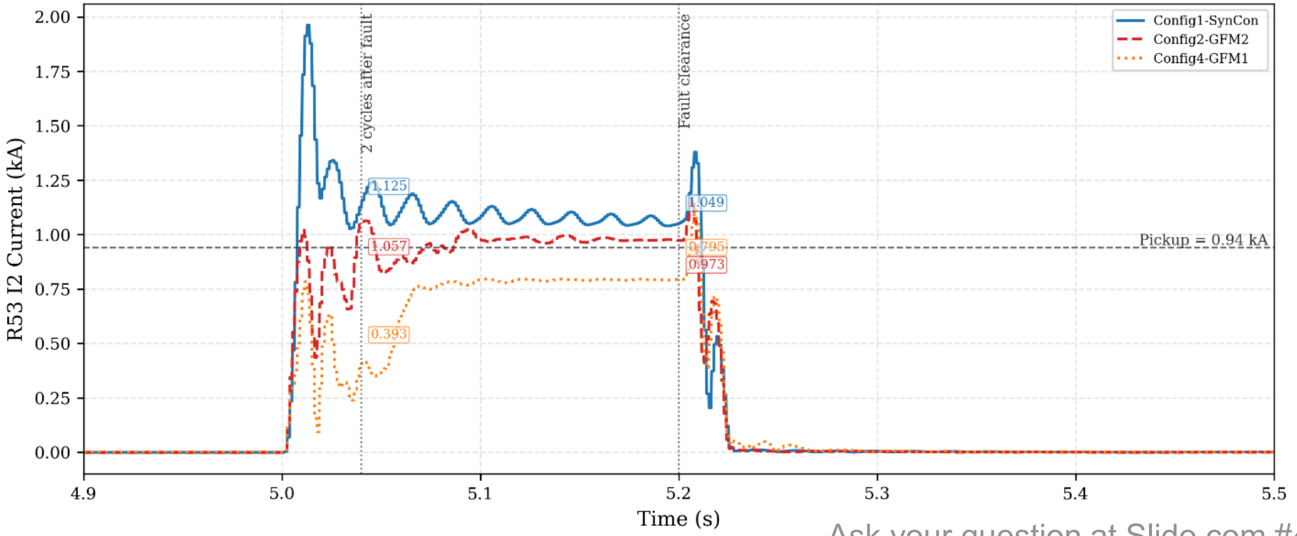
What has been established so far?



Fault current characteristics that matter…

- Magnitude and duration (sustainability of response).
- Speed of response and settling time.
- Negative sequence capability (amplitude and phase angle).
- Stability of response (oscillations and general variability).
- Ability to resist change in terminal voltage phase angle during fault.



Some key takeaways…

- Literature review, backed up by simulations and preliminary hardware in the loop (HIL) relay testing, confirms that relay misoperation is possible.
- Protection elements reliant on current magnitude and negative sequence quantities appear most susceptible – examples include:
  - Over current protection
  - Distance protection (directional schemes)
  - Directional earth fault comparison
  - Power swing schemes
- Variability across OEM platforms exist at present – efforts to standardise GFM is an ongoing activity at an international level, e.g. updates to the IEEE Standard 2800 Series (IEEE SA - P2800.1).
- Increasing need to improve modelling of IBR in short circuit analysis software – aim should be to minimise EMT simulation and bespoke study requirements where possible.

Firming up the role of GFM BESS to support network protection

Insight #2 – Andrew Halley

Where to from here?

Ongoing activities sit within AEMO System Strength workplan…

A. Protection focused technical forum

- Proposed collaboration between NEM *network service providers* focusing on existing and future protection related issues – an existing NEM working group will be utilised for governance purposes.
- Specific Terms of Reference (TOR) to be prepared Q4 2026. Kick-off in Q1 2027.

B. Transitional Services - Type 2 Service Trials

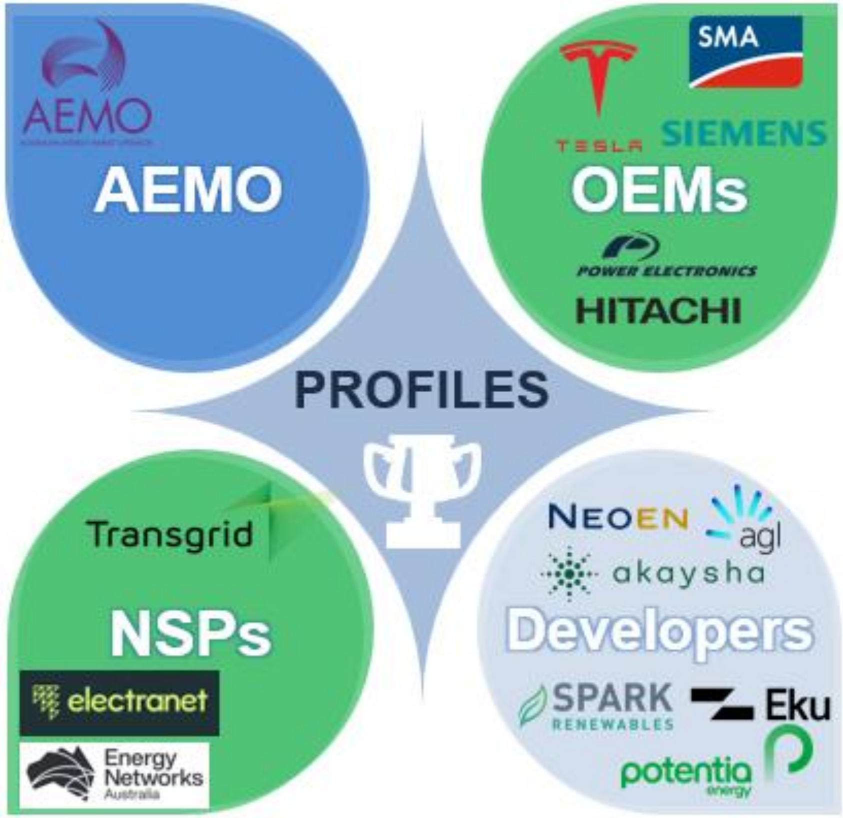
- Grid Forming Inverter Protection Quality Fault Current Trial.
- Zero Synchronous Generation Trial.
- Details available from: AEMO | Transitional Services - Type 2 Services.

C. Industry collaboration via the UNSW PROFILES Project

- See next slides.

PROFILES Project – [Link to ARENA Projects Page]

- **P**rotection & **R**elay **O**peration **F**or **I**nverter-based **L**ow-inertia **E**lectrical **S**ystems (PROFILES) – ARENA funding[1] announced on 12 August 2026.



- Collaboration between the University of New South Wales (UNSW) and industry stakeholders.
- Deployment, evaluation and testing of multi-OEM inverters and protection devices in a real time simulator (RTS) environment.
- Inaugural Project Steering Committee Meeting held September 2026, aiming to conclude in Q4 2029.
- **Conscious that industry is looking for guidance on GFM BESS now, so early results will be a focus!**

[1] This Project received funding from the Australian Renewable Energy Agency (ARENA) as part of ARENA's Advancing Renewables Program.

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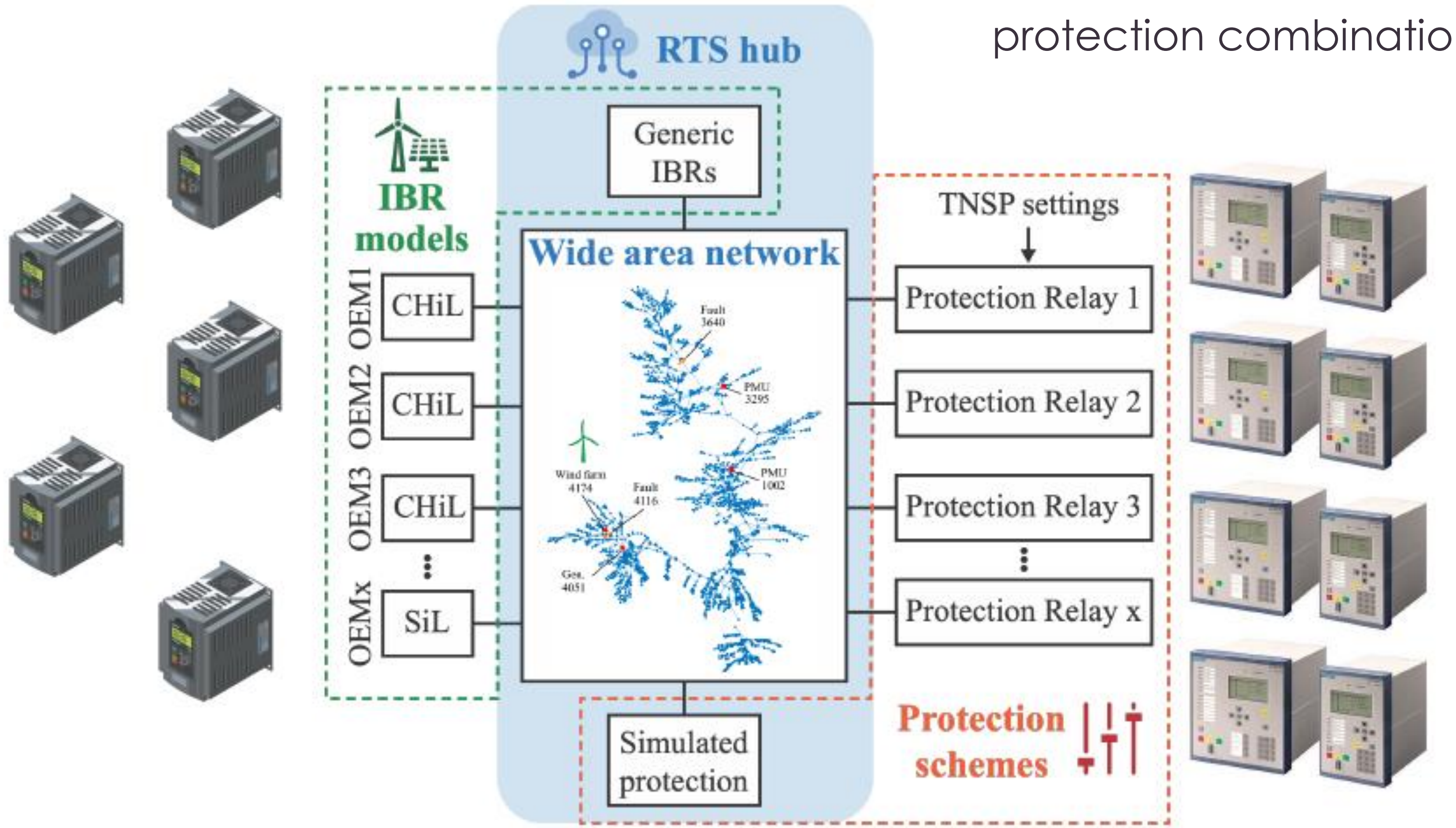
PROFILES Project

Real Time Simulator (RTS)



OEM specific testbeds will be used to examine individual control and protection combinations.

Wide area testbed will bring controllers and protection relays together in a closed loop simulation utilising **controller hardware in the loop (CHIL)** and **software in the loop (SIL)** representations of physical equipment.

PROFILES Project

Breaking News...Interested parties can signup to receive public PROFILES reports at ARENA's PROFILES project page

Key objectives include...

- Develop evidence-based understanding of protection relay performance in power systems with significant IBR capacity installed.
- Reduce uncertainty associated with how GFM converters respond to disturbances and how protection systems interpret these responses.
- Develop guidance on mandatory versus discretionary control behaviours from IBR.
- Identify pathways for protection system design and operation in IBR dominated power systems.

This is an industry collaboration, and combined effort will be needed to ensure we arrive at practical and implementable outcomes.

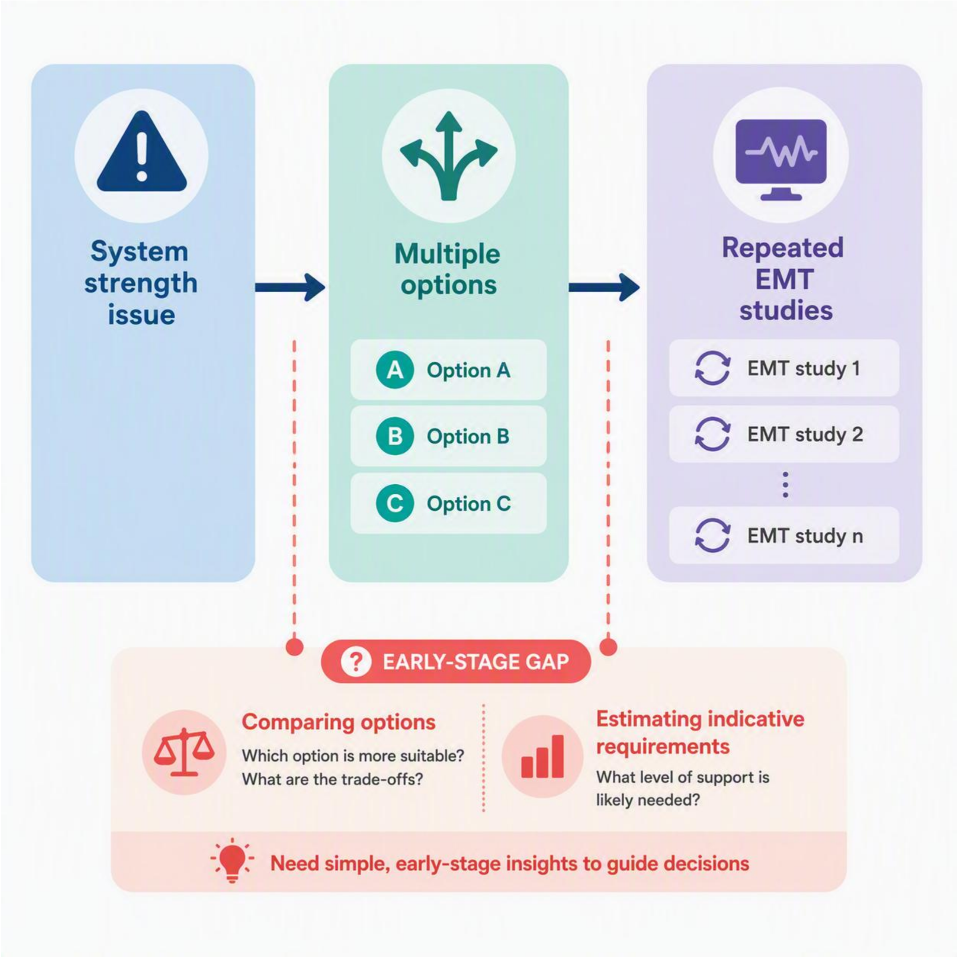
Further participation from industry is welcome (please feel free to contact):

Mark Twidell (m.twidell@unsw.edu.au) or Georgios Konstantinou (g.konstantinou@unsw.edu.au)

Quantifying System Strength Support

Insight #3 – Jingwei Lu

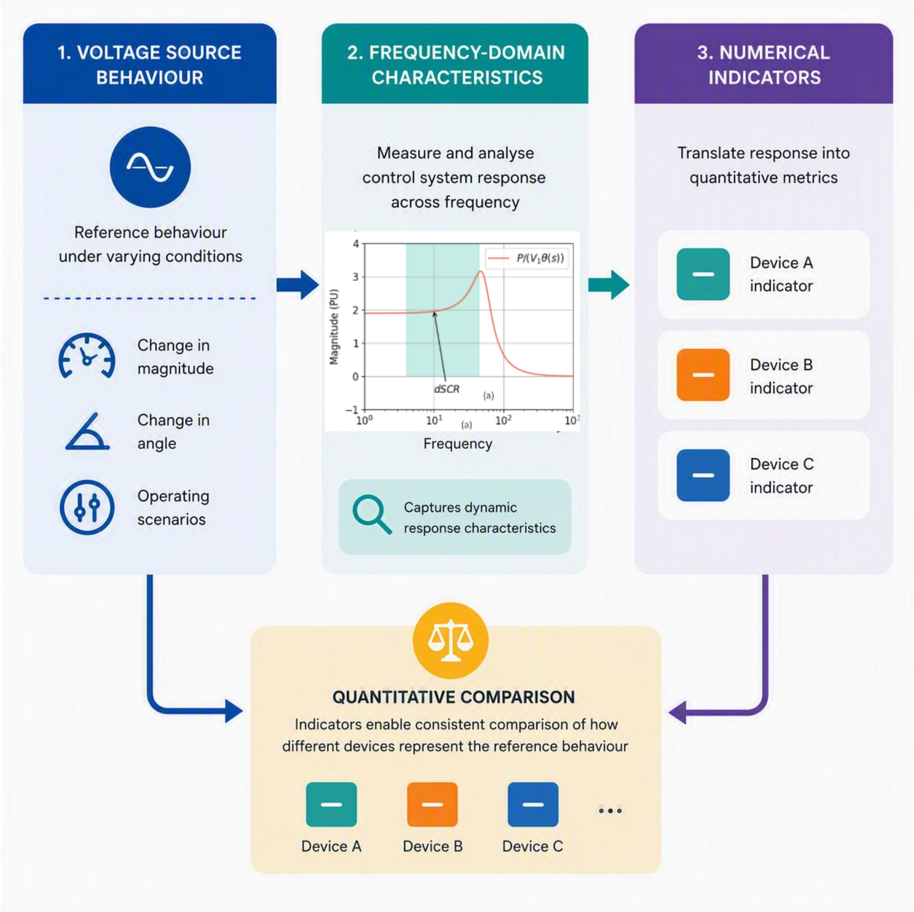
Frequency-domain indicators to support early screening



- Detailed EMT studies essential for system strength assessment.
- Comparing remediation options often relies on iterative, trial-and-error EMT simulations.
- Results can show whether an option resolves the studied issue, but do not directly quantify and compare each device's contribution.

Can we quantify system strength support earlier, to guide assessment scoping and focus detailed EMT studies?

Making dynamic system strength support measurable



- System strength support is characterised through a device's voltage-source-like behaviour, i.e. active and reactive power response to changes in voltage magnitude and angle.
- Frequency-domain scans reveal the device's voltage-source-like behaviour over the relevant frequency range.
- The scan results are translated into numerical indicators for comparing specific devices and control settings.

Frequency-domain analysis can quantify and compare the dynamic system strength support of specific devices and control settings.

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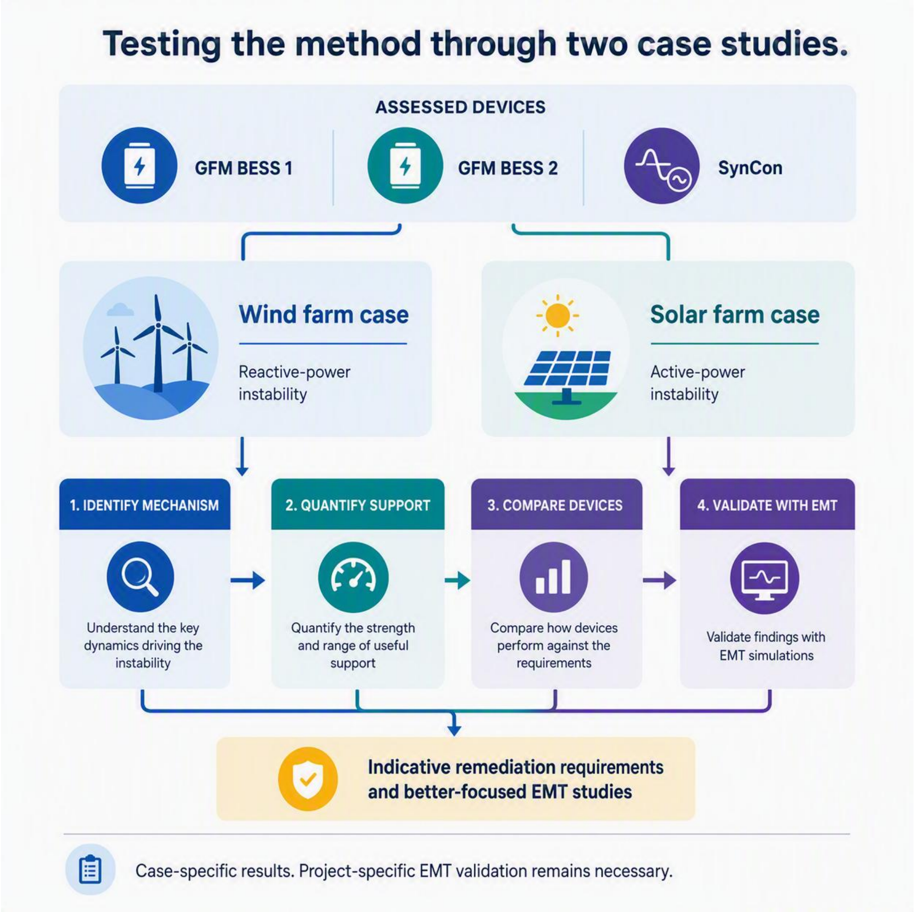
From measurement to indicative remediation sizing



- Frequency-domain scans were used to quantify the dynamic system strength support from two GFM BESS models and one synchronous condenser.
- The resulting indicators were applied to two GFL IBR instability cases to estimate the support required for stable operation under the studied grid conditions.
- EMT simulations validated the predicted stability boundaries, providing confidence in the method's use for indicative device sizing.

The method links measurable device capability to early assessment and indicative sizing of system strength remediation options.

Earlier insight to guide focused detailed studies

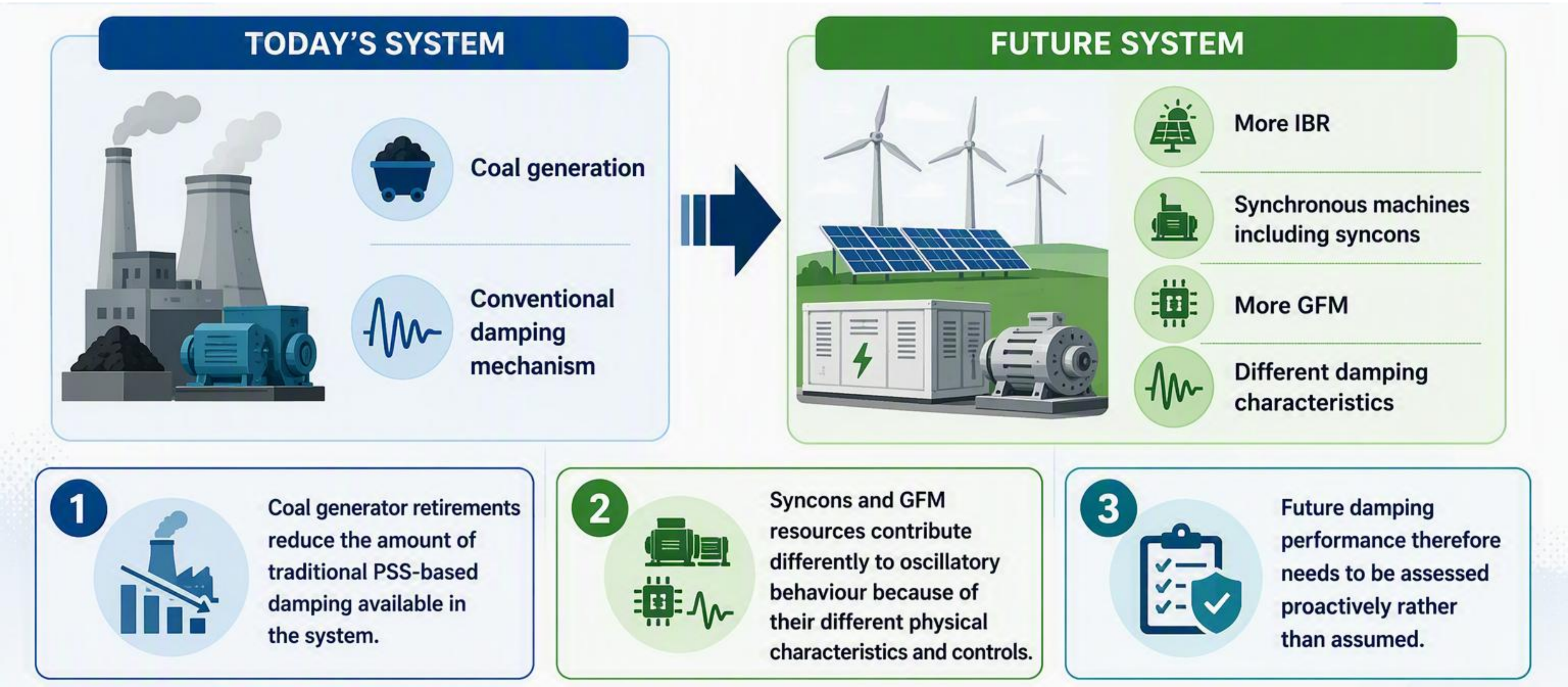
- Compare credible remediation options earlier, reducing repeated trial-and-error EMT simulations during initial assessment
- Estimate indicative support requirements and device capacity, supporting earlier consideration of remediation costs and connection pathways.
- Focus detailed EMT studies on the most relevant options and conditions, while retaining project-specific validation.

Potential benefit for developers and NSPs: earlier comparison and indicative sizing of remediation options, helping inform connection pathways and focus detailed EMT studies.

Future damping trends

Insight #4 – Jingwei Lu

Future system damping needs attention



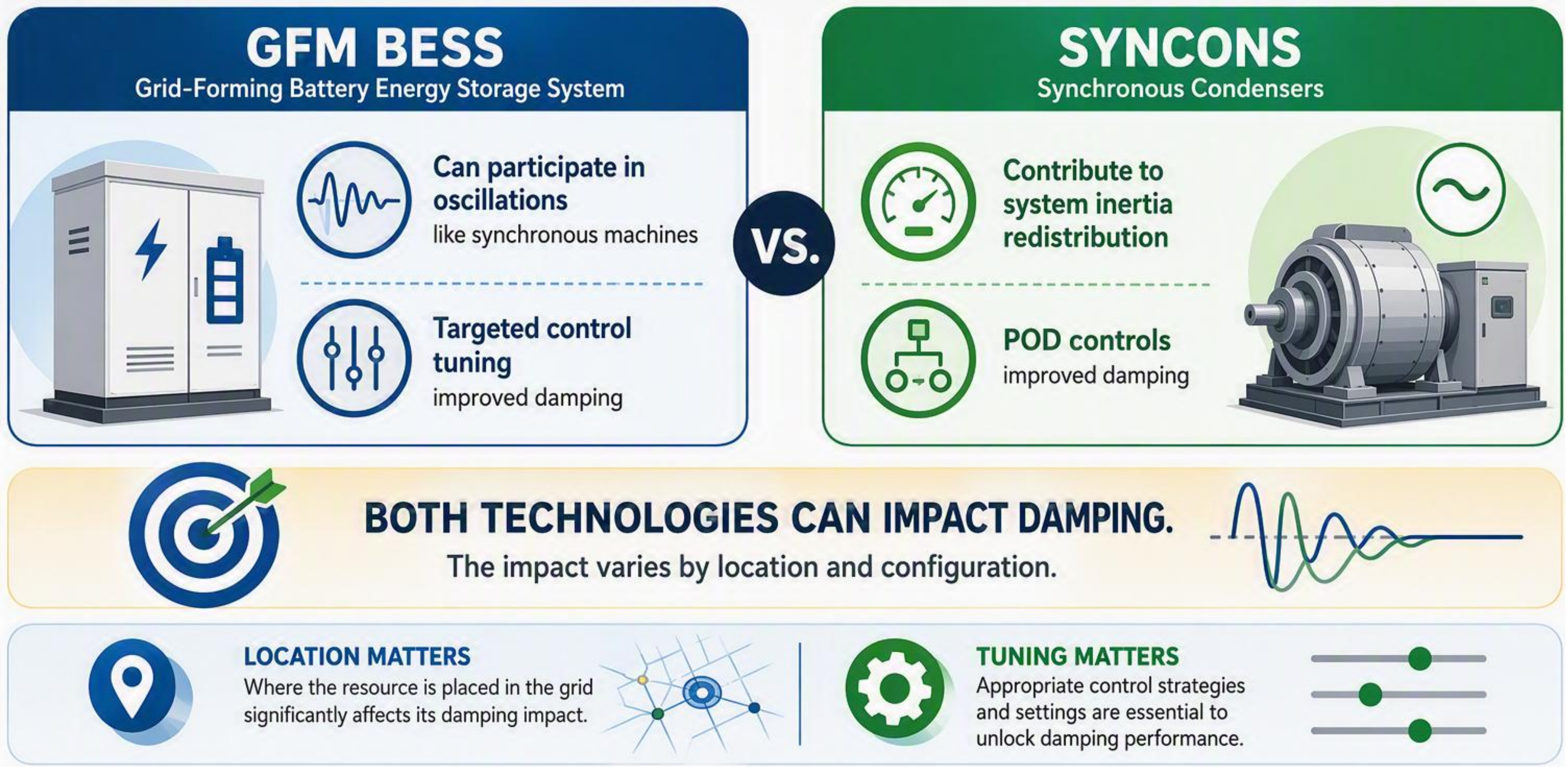
Energy transition changes not only generation technologies, but also the mechanisms that provide oscillation damping.

Damping risk identified in studied future power system

- A repeatable inter-area oscillation was observed in the studied future high-demand conditions.
- The response remained evident across a range of tested contingencies and future system assumptions.
- The findings point to a combination of interacting system changes rather than a single dominant driver.

The study demonstrates the value of identifying emerging damping risks before future network, plant and control decisions become difficult to change.

What we learned about GFM and syncons



Effective damping comes from how resources are controlled, tuned and integrated

Looking ahead to changing system stability needs

- Study potential future system conditions early to identify how core stability phenomena may change as synchronous generation retires and new resources connect.
- Preserve practical, low-regret options: consider supplementary POD capability in new syncon specifications where a material need is identified.
- Build confidence progressively through model validation, and transition-point assessments at key transition points, informing future planning and project decisions.

Engineering Roadmap: looking ahead to how system stability may change, providing earlier visibility for planning and investment decisions, and preserving practical options before designs are locked in.

Study report to be published in next two months prior to 2026 TPSS

Next steps

Senah Javed

What to expect for the rest of FY26

IBR Impacts on Power System Protection
UPCOMING

GFM Inverter Fault Current Performance
UPCOMING

Inter-area Oscillation Damping
UPCOMING

Transition Plan for System Security 2026
UPCOMING

Type 2 Services/Trials

PROFILES

Q&A

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