Operating a power system on 100% Distributed Resources

Challenges and paths forward

Dr Jenny Riesz – Manager – Operational DER Management

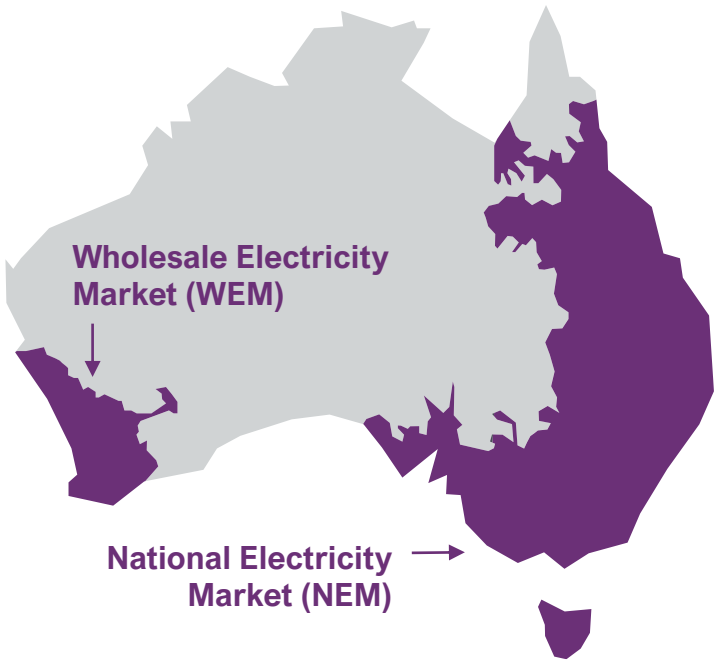
About AEMO

- 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)

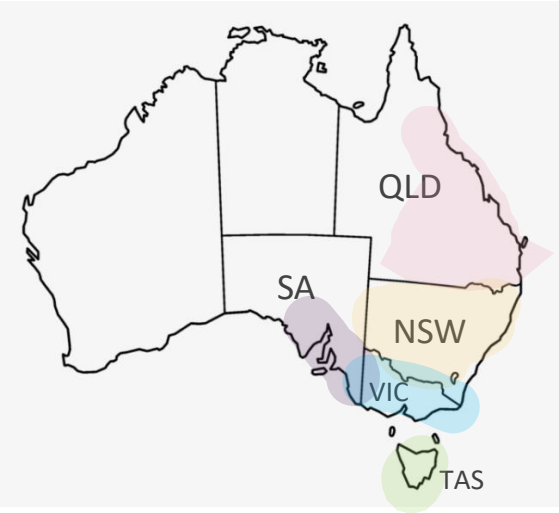
Short Term Trading Market (STTM)

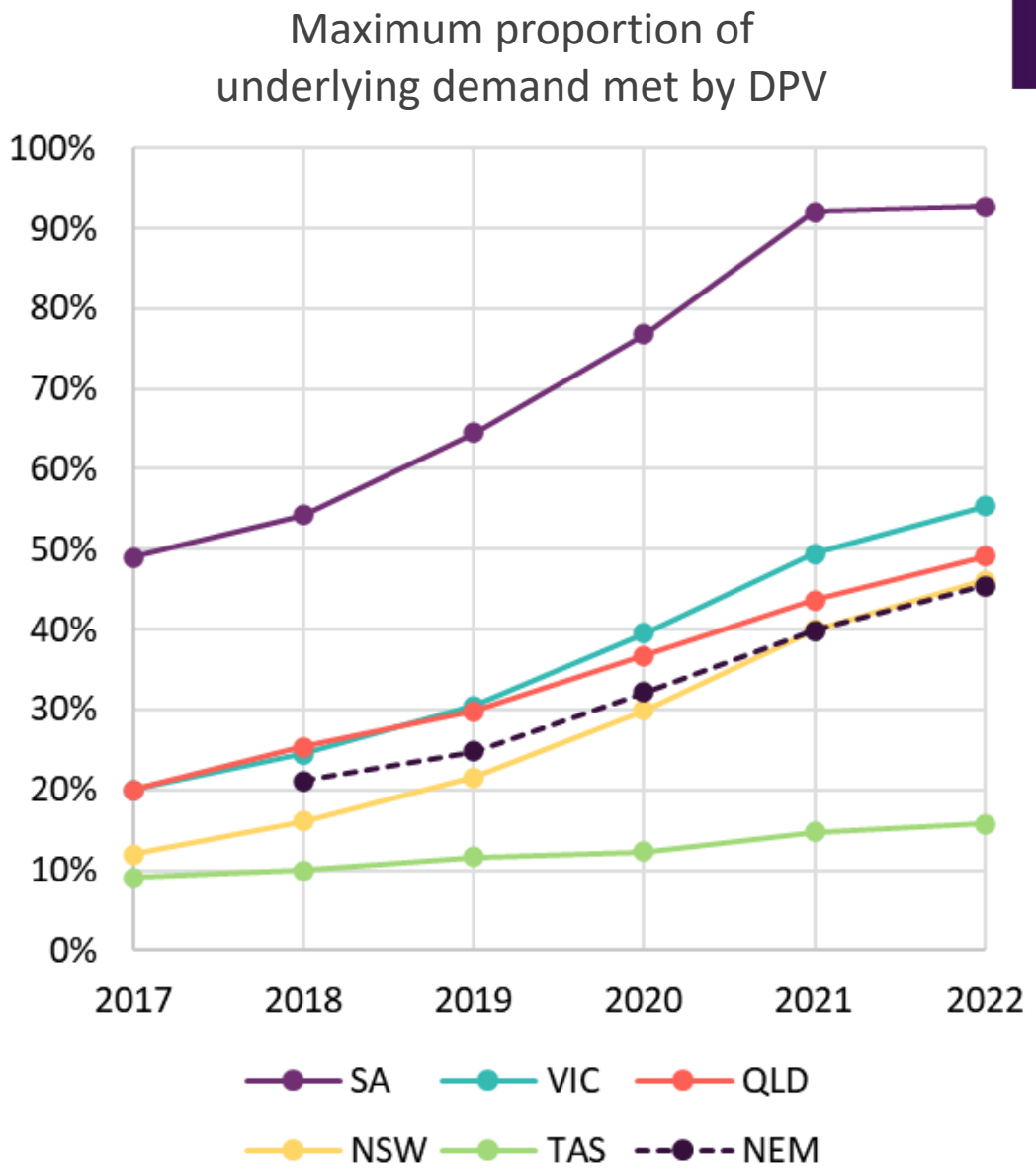
and

Gas Supply Hub (GSH)

Distributed PV

- Significant proportion of demand now met by distributed PV

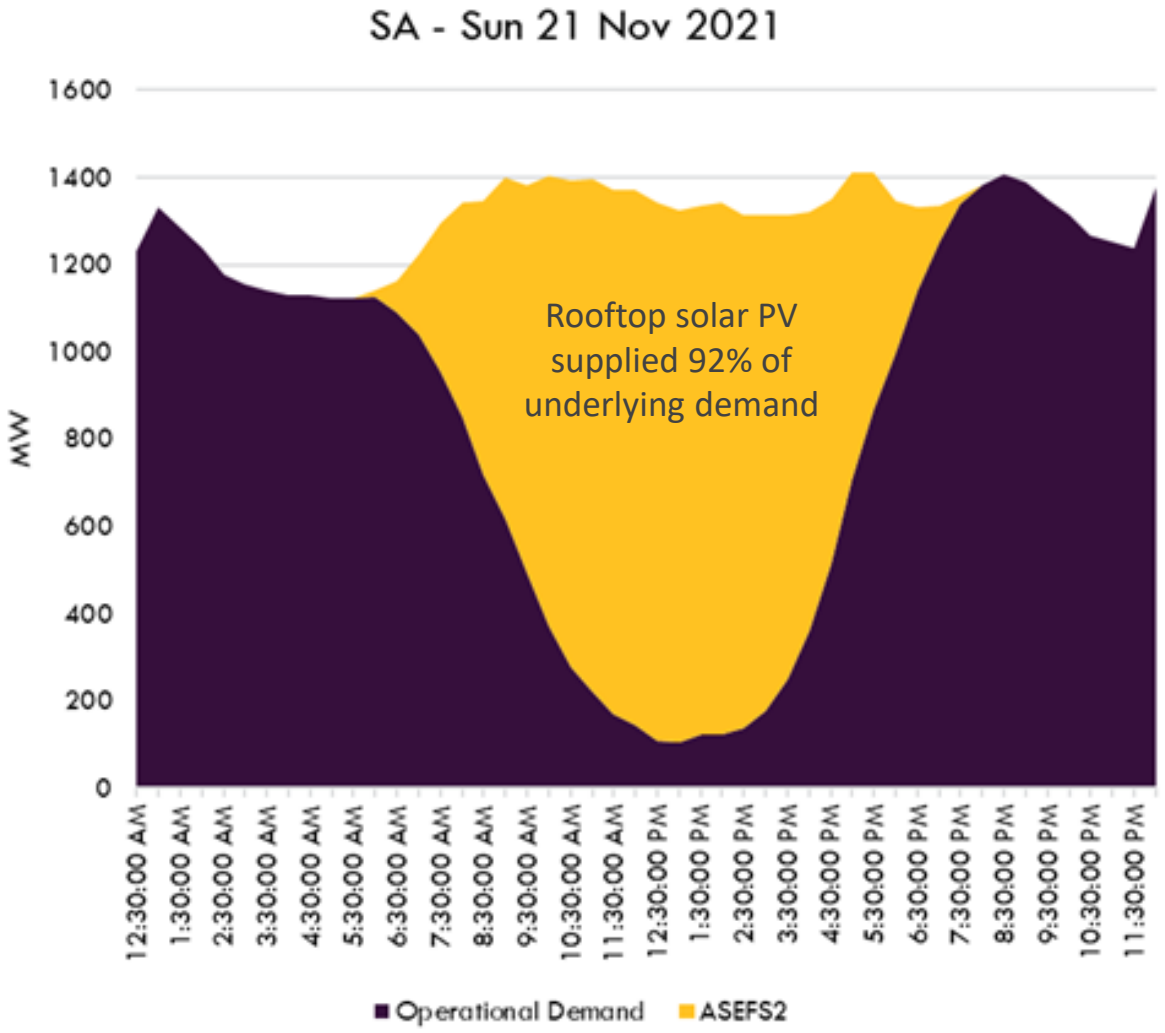




South Australia

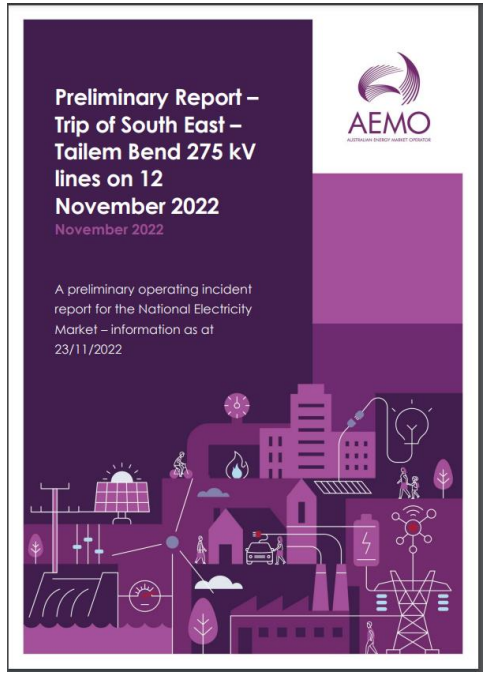
- ~2 GW of distributed PV
- Growing at ~20 MW per month
- Supplying up to 92% of underlying demand
- Minimum operational demand record to date: 104 MW

- How do we operate a major power grid on only distributed resources?
- What challenges will arise?
- How do we address challenges, removing barriers to growth in distributed resources?



Incident: 12-19 Nov 2022

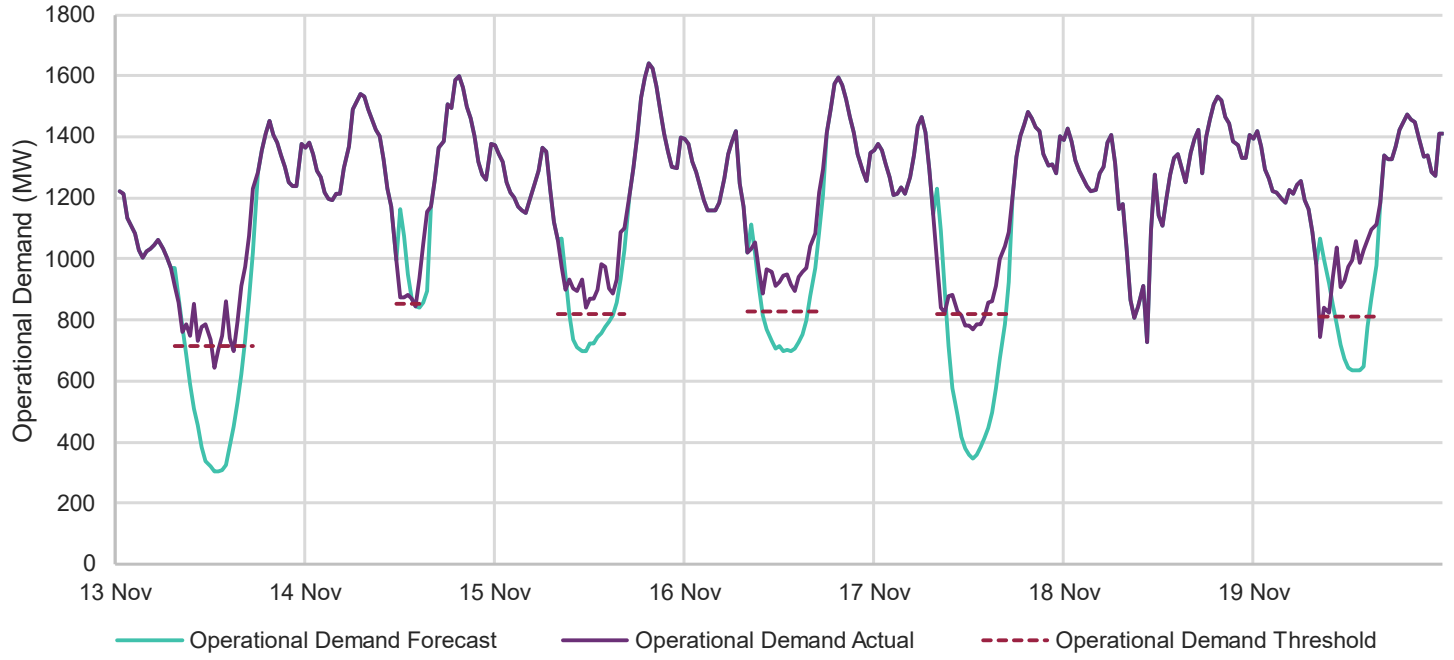
- 1639hrs on 12 November 2022: Non-credible contingency on multiple transmission lines (severe weather condition) causing synchronous separation of majority of SA power system from rest of the NEM
- Operated majority of SA as an island until 19 November 2022
- Included operation through some periods of high generation from distributed PV (DPV), necessitating DPV curtailment to maintain adequate frequency control services for power system security
- Successful operation of a giga-watt scale island power system through high DPV periods and enactment of emergency backstop DPV curtailment methods
- Many valuable learnings to improve processes and frameworks

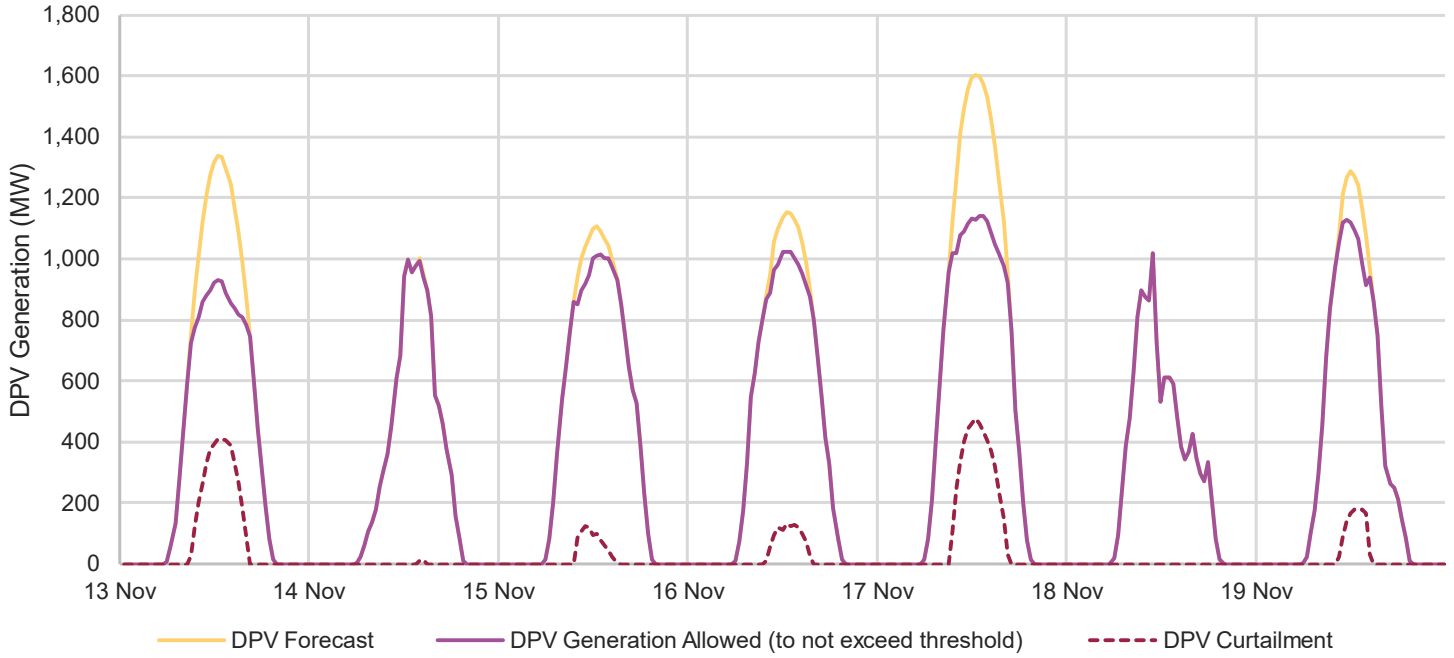


https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2022/preliminary-report--trip-of-south-east-tailem-bend.pdf?la=en

Island operation

Main reason for DPV curtailment was to manage frequency impacts of possible DPV shake-off in response to a major fault in the South Australian island

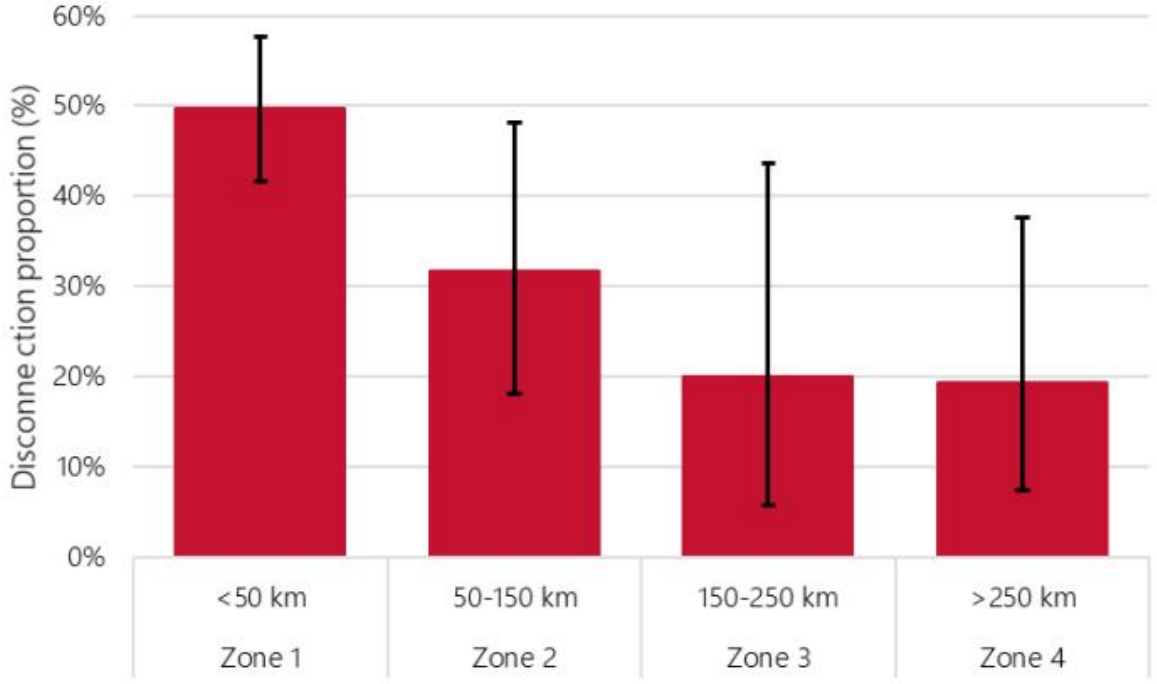


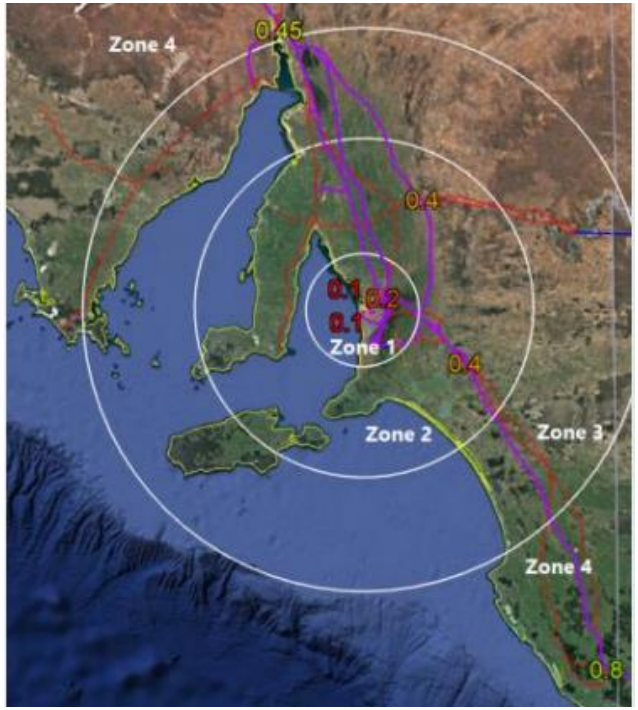


Distributed PV unintended disconnection

- Up to 40% of distributed PV in a region can disconnect in response to power system disturbances

Example disturbance in South Australia (3 March 2017)





AEMO (May 2021) Behaviour of distributed resources during power system disturbances, https://aemo.com.au/-/media/files/initiatives/der/2021/capstone-report.pdf?la=en&hash=BF184AC51804652E268B3117EC12327A

Managing DPV unintended disconnections

Improve standards

- AS/NZS4777.2:2020 mandatory from Dec 2021
- Compliance???
- Will it be sufficient and effective????

Then to manage legacy systems:

Network constraints
- Operate network within stability limits, accounting for larger contingency sizes

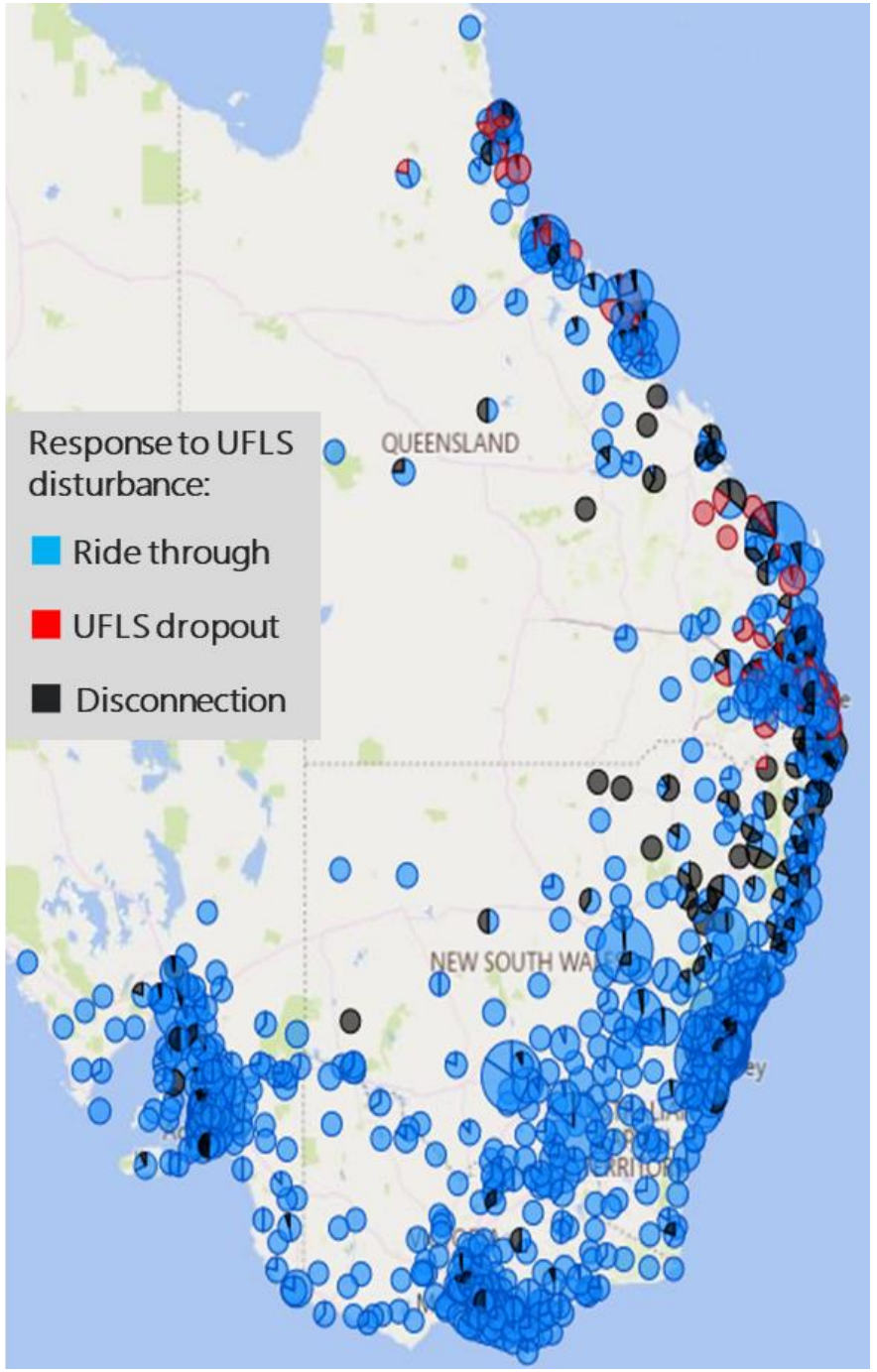
Frequency Control
- Enable sufficient frequency reserves to manage larger contingencies

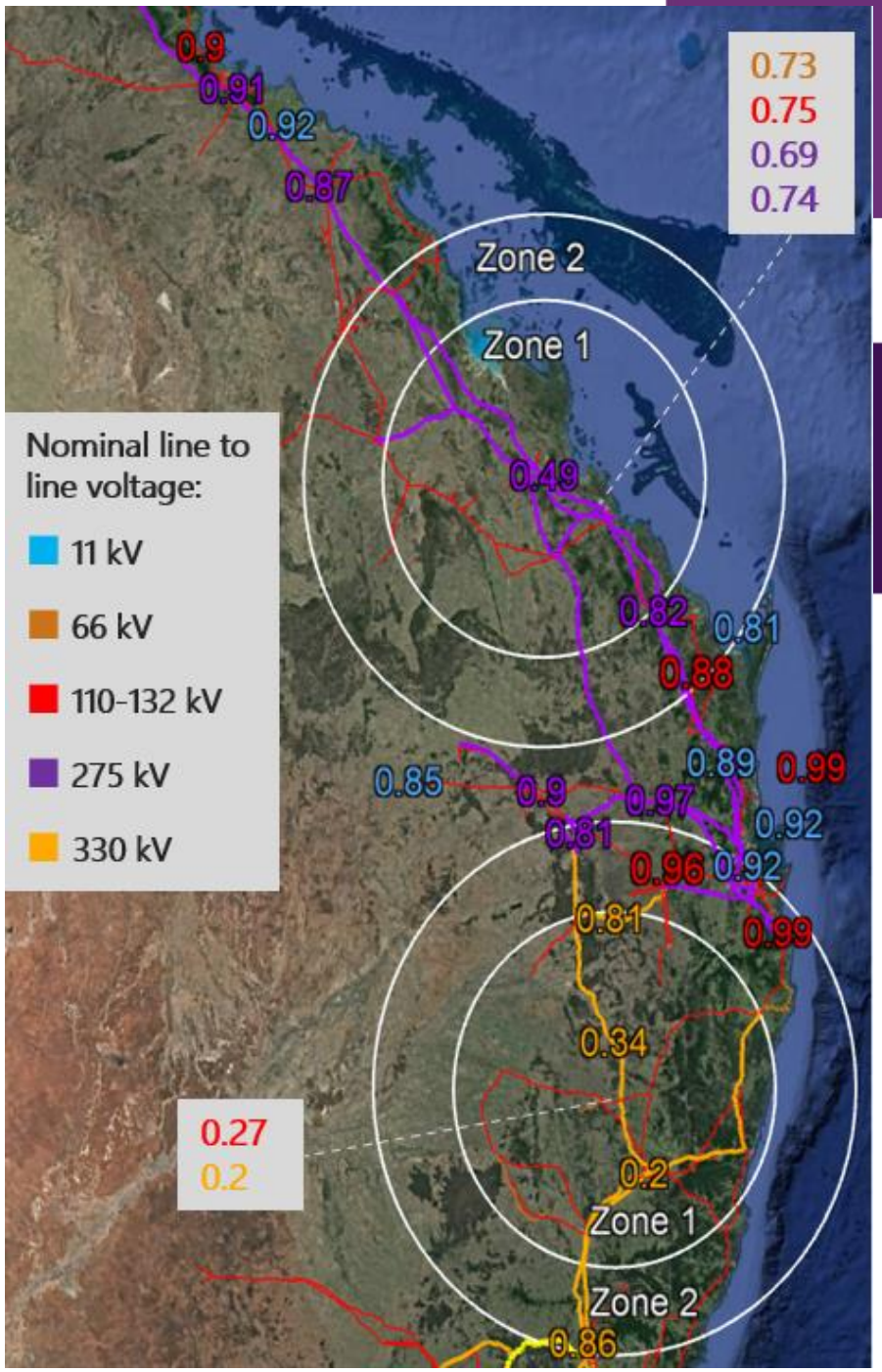
Operating procedures
- Maintain contingency sizes within limits when operating with line outages
- Revoke permission for line outages if need be
- Curtail distributed PV as last resort

Need to accurately estimate distributed PV tripping behaviour

Data!

- Significant DER behaviours interacting with grid behaviour
- Cross-matching Solar Analytics datasets with others (e.g. Tesla)
- Project MATCH
- Data, data, data!
  - Reduce uncertainty
  - More confidence in intervention measures
  - Reduce need for conservative intervention
- Care around dataset bias



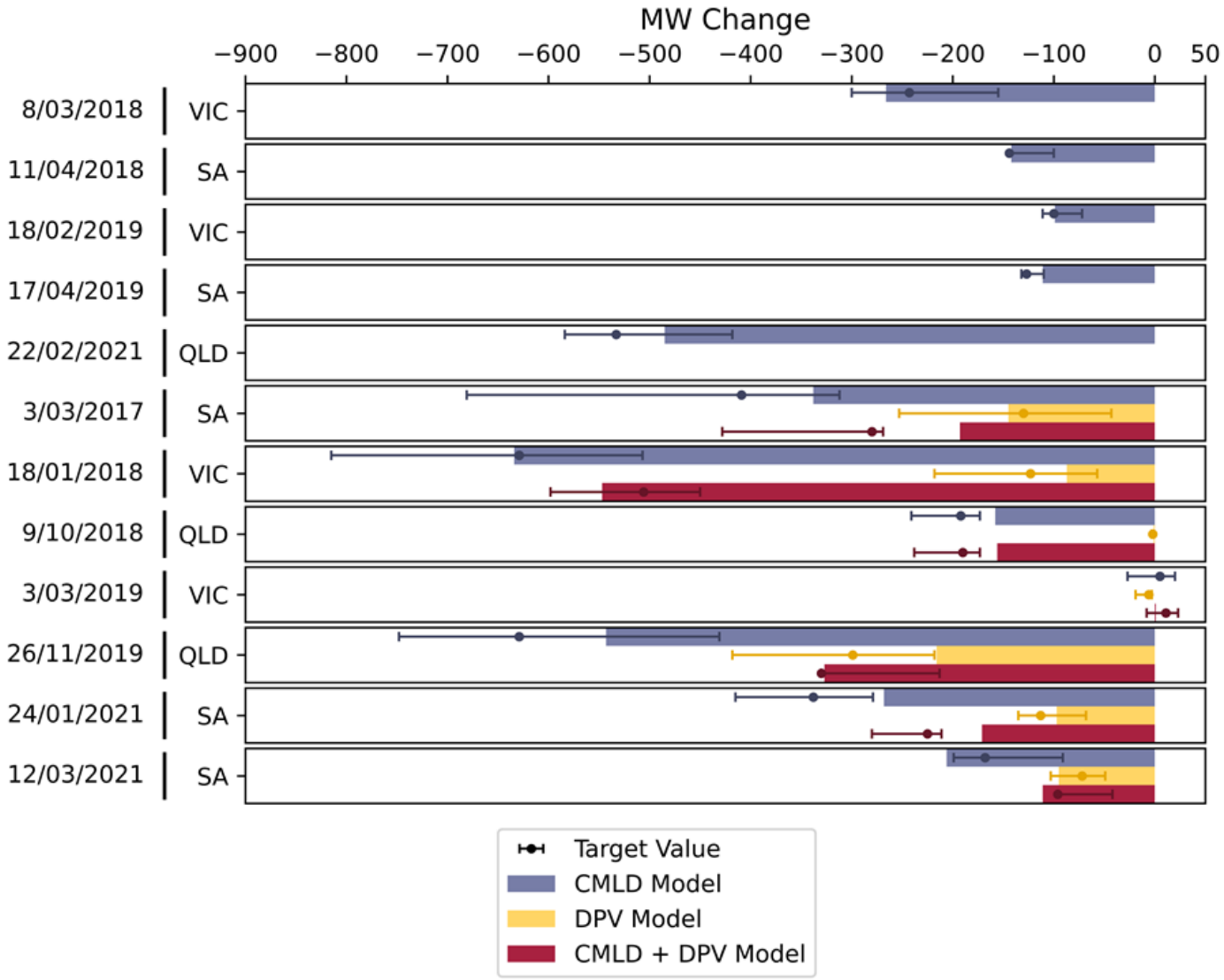


AEMO (Oct 2021), Trip of multiple generators and lines in Central Queensland and associated under-frequency load shedding on 25 May 2021, https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2021/trip-of-multiple-generators-and-lines-in-qld-and-associated-under-frequency-load-shedding.pdf?la=en&hash=F873AE26F7540FCE817AD193BAFD07D9

Importance of data

- Significant implications
  - Planning studies
  - Real-time operations
- Uncertainty: ±25% of contingency size
  - Significant uncertainty in input datasets
- Better data required for further model improvements
  - Load composition
  - DPV behaviour
  - High speed network measurements

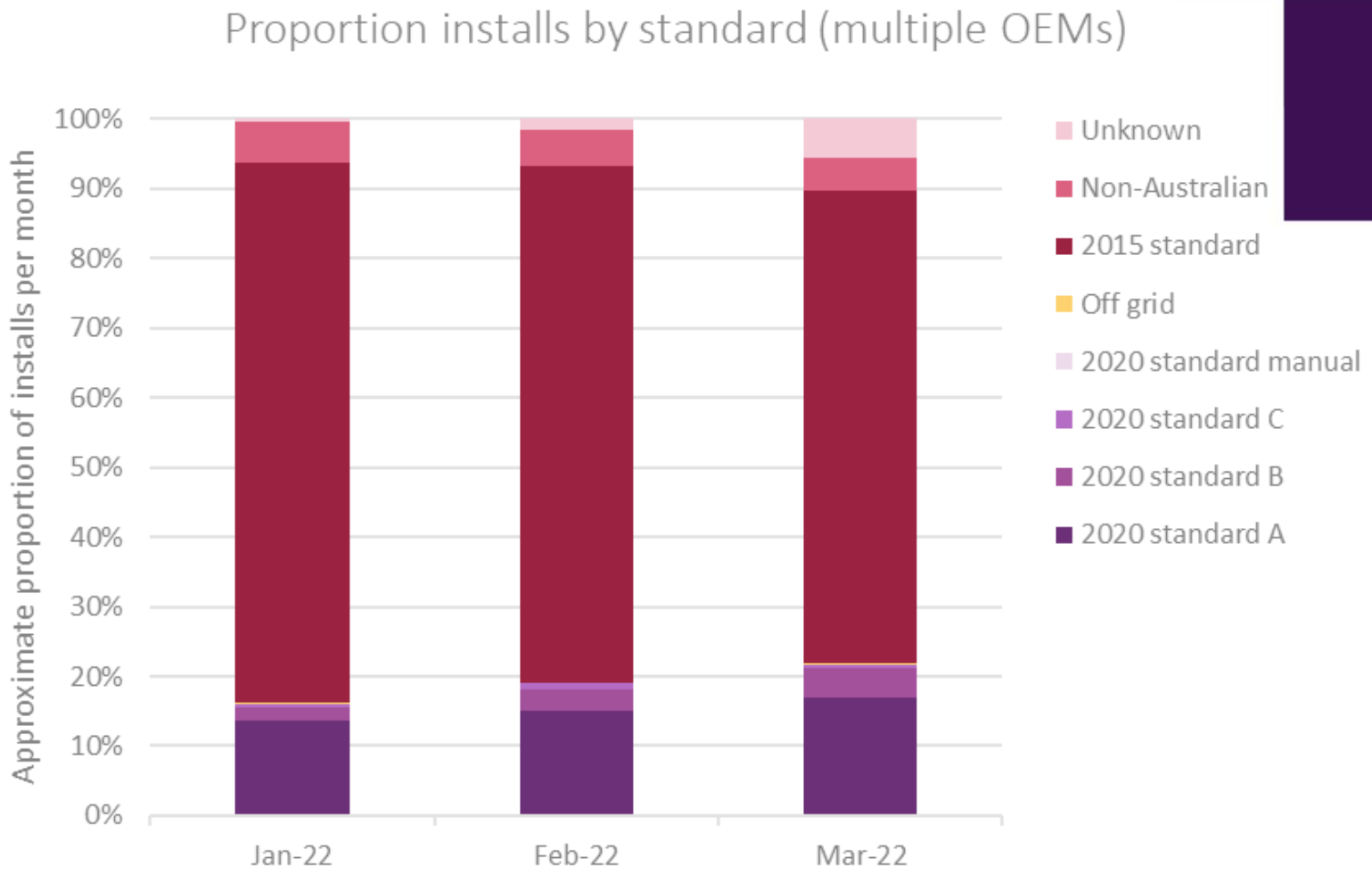
RMS model performance at representing load/DPV tripping in voltage disturbances:



AEMO (November 2022) PSS®E Models for load and distributed PV in the NEM, https://aemo.com.au/-/media/files/initiatives/der/2022/psse-models-for-load-and-distributed-pv-in-the-nem.pdf?la=en

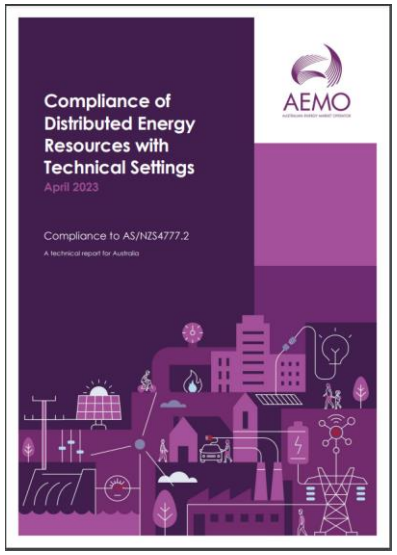
Compliance with technical standards

- 10 manufacturers provided installation data since 1 Jan 2021
- Suggests that only ~40% are being set correctly to AS/NZS4777.2:2020 Standard
- Majority are being set to older 2015 standard



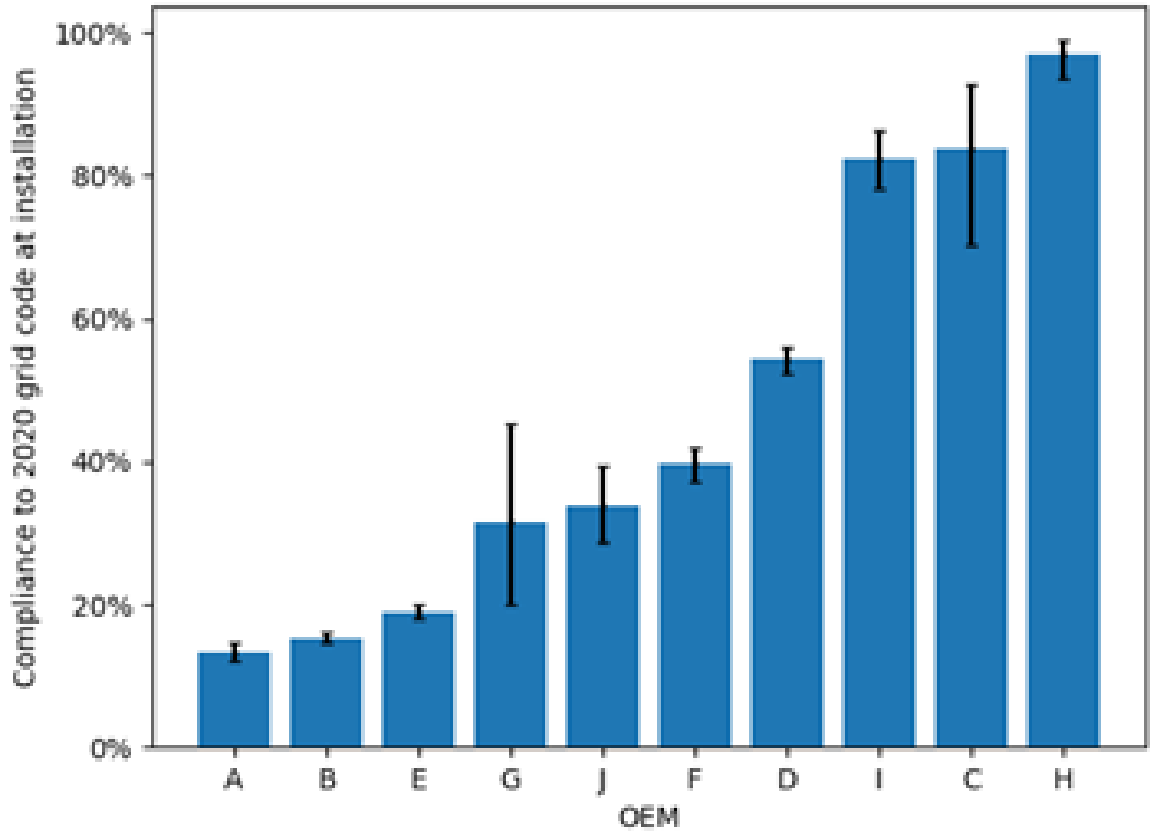
Compliance with standards

- Compliance rates vary significantly between Original Equipment Manufacturers (OEMs)



https://aemo.com.au/-/media/files/initiatives/der/2023/2023-04-27-compliance-of-der-with-technical-settings.pdf?la=en&hash=19A1CACD35565DAC69610542B2292DB3

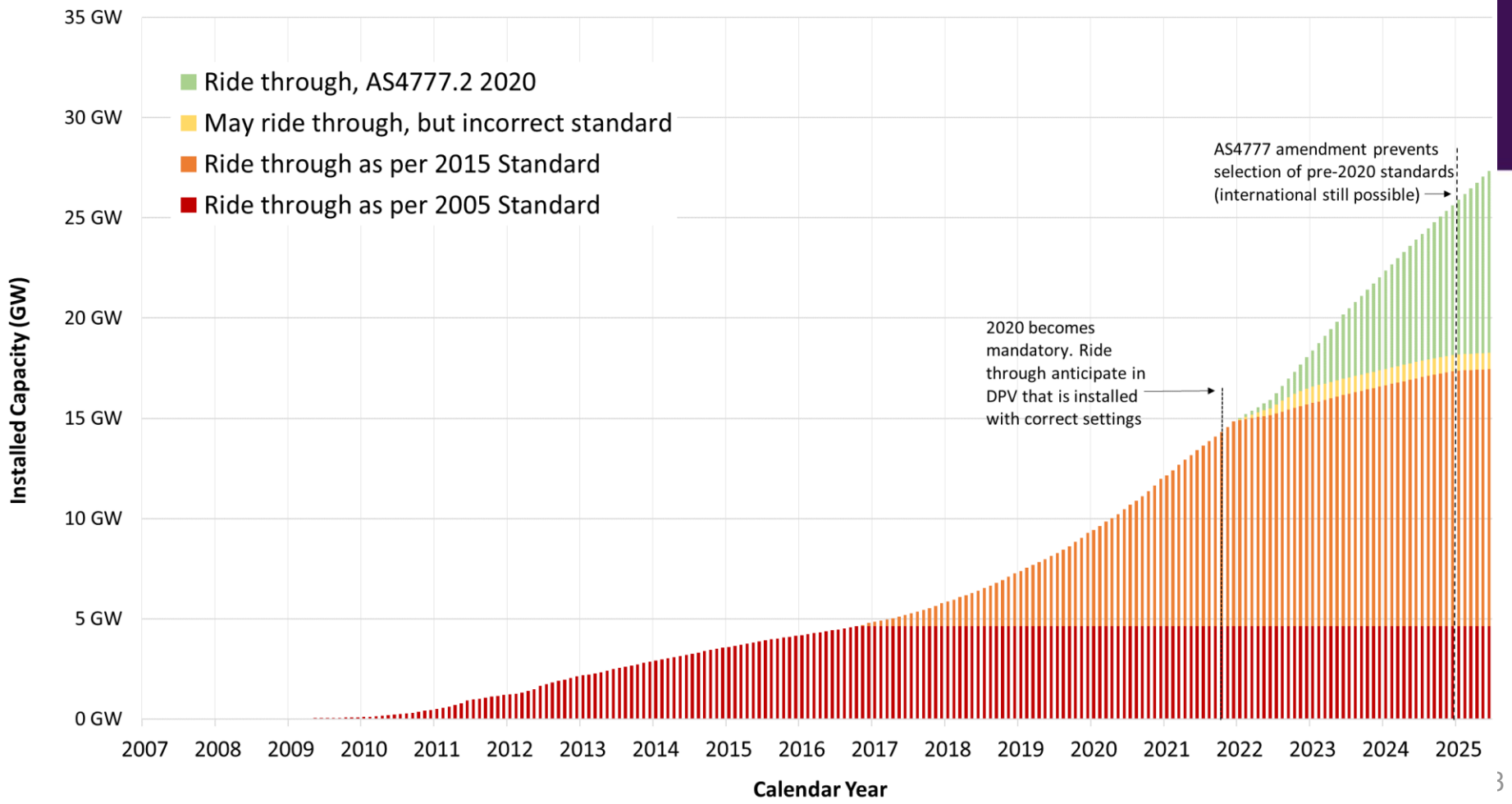
Compliance rates to 2020 standard (Q1 2022 installs in the NEM)



Disturbance ride-through behaviours

- Working with Distribution Network Service Providers, OEMs and other market bodies to address
- Immediate actions
- Enduring governance frameworks

NEM fleet projections:



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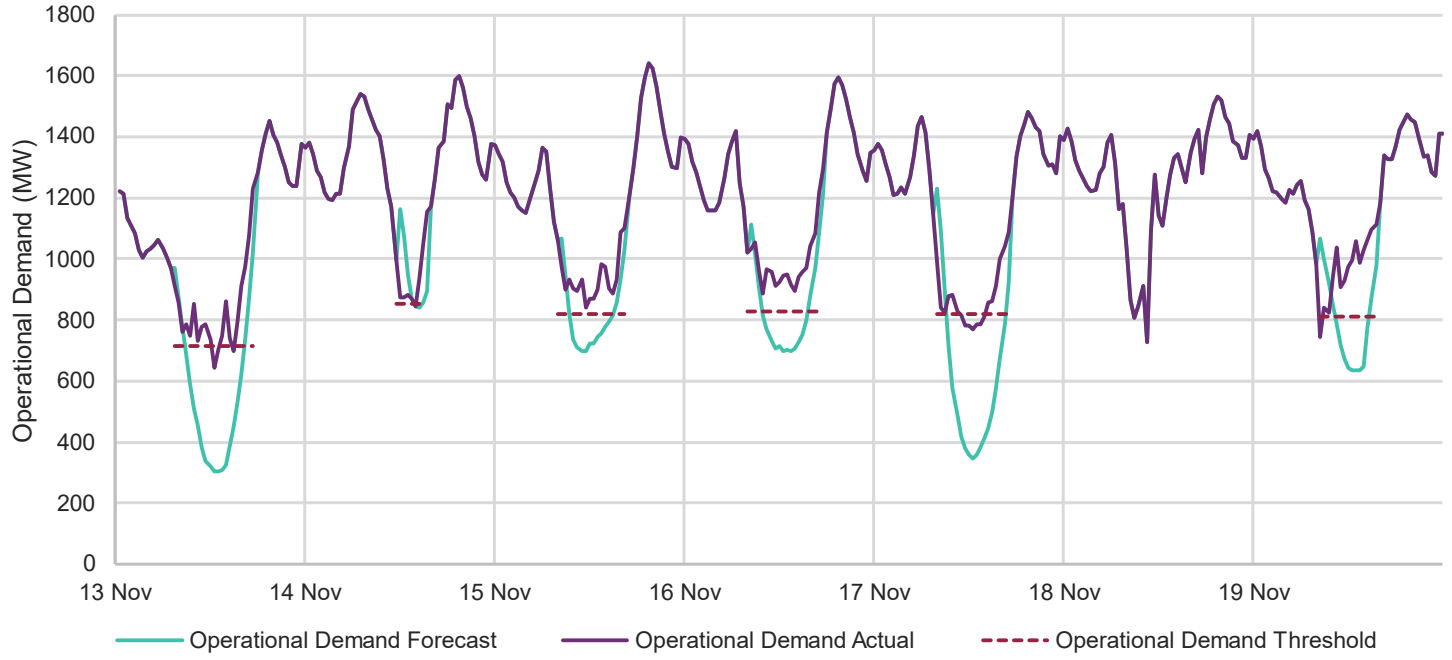
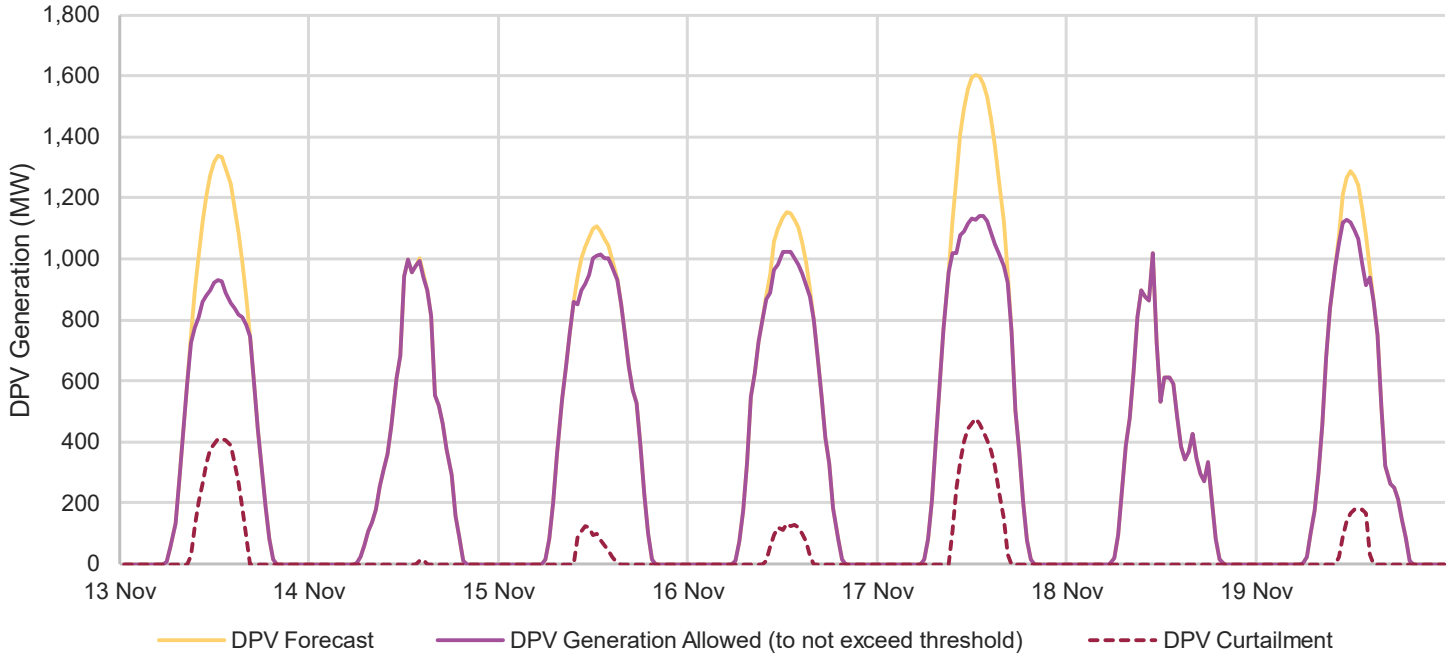




Emergency backstop PV curtailment

- Introduced emergency capability to curtail distributed PV when required for system security
- Analogous to load shedding
- Used as a last resort, after all other measures have been exhausted
- Anticipate using very rarely
- Can be simple implementation, with more sophisticated capabilities to follow
- In parallel:
  - Explore other ways of providing essential services in minimum demand periods
  - Market development

https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/sa_advisory/2020/minimum-operational-demand-thresholds-in-south-australia-review.pdf?la=en&hash=BBB27149A93B9259C63B47A8ECDB0B6E

DPV curtailment mechanisms

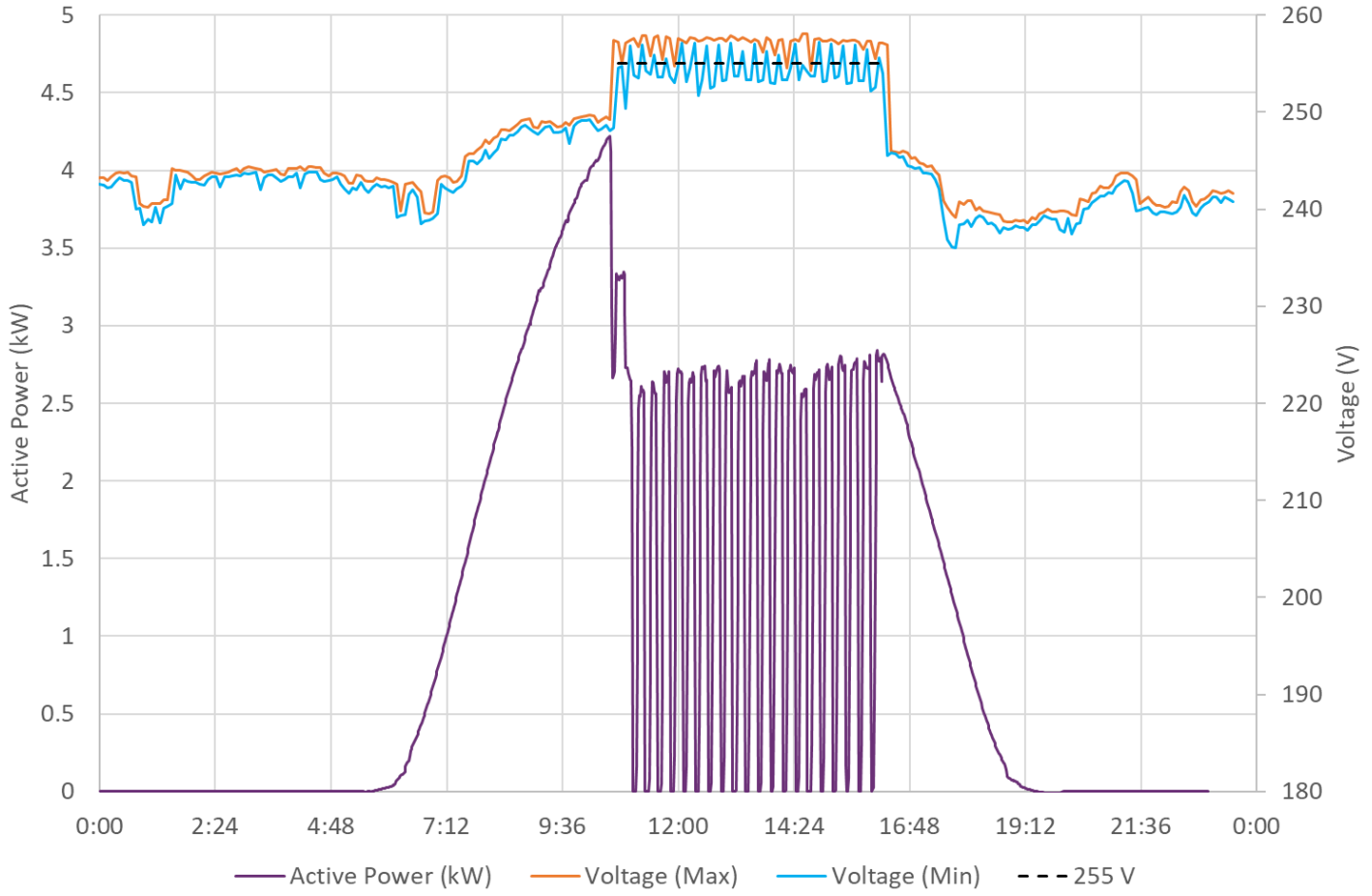
Mechanism	Observations in 12-19 Nov 2022 event
SCADA controlled generation • Systems >200kW have SCADA control	Responded as expected
Smarter Homes / Relevant Agents • From 28 September 2020, all DPV in SA must comply with Smarter Homes regulations and appoint a Relevant Agent responsible for managing active power from DPV systems during state electricity security emergencies. • 517 MW of DPV installed that should fall under this requirement • There are now more than 50 different Relevant Agent – Technology combinations requiring direction via phone-calls.	• Poor compliance observed • Biggest erosion of response is from incorrect commissioning • Further reduction in response rates observed on 13/14 Nov due to telecommunications outages • Widely varying responses from different technology providers
Enhanced Voltage Management • Increase distribution voltages to reduce DPV generation	Delivered majority of response

Enhanced Voltage Management

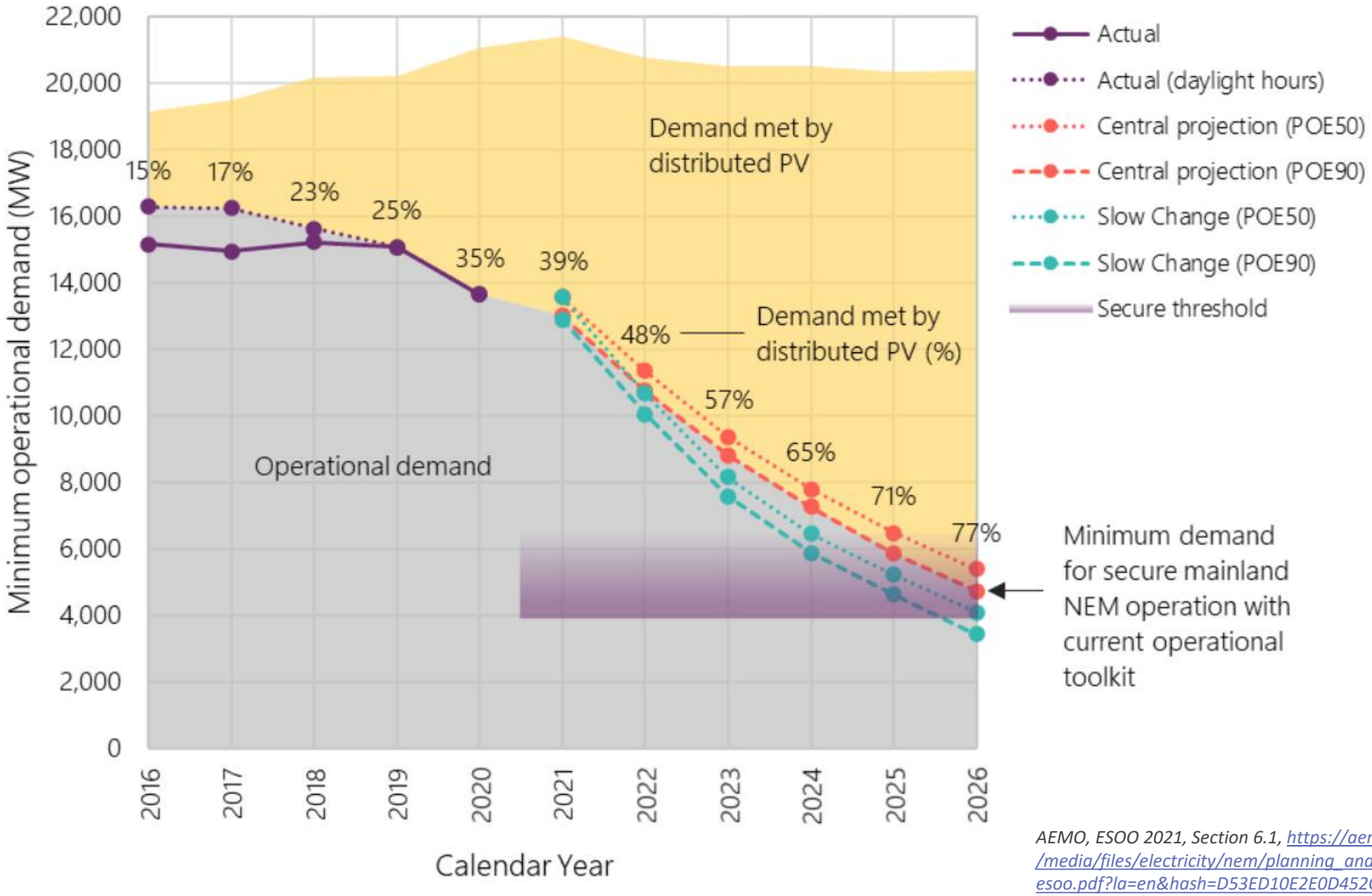
- Increase distribution voltages to reduce DPV generation
- Estimated that at least 2/3 of DPV curtailment in this event was delivered by EVM
- Would likely have been insecure without EVM, especially on 13/17/19 Nov
- Does not rely on availability of internet or telecommunications, and delivered a consistent and reliable response on 13 and 14 November during telecommunications loss

Limitations of EVM

- Observations of inverter cycling (15-20min cycles from 10-15% of DPV systems)
- Cannot discriminate between inverters on a feeder – may have impacted FCAS delivery from VPPs
- Investigating implications for use in a system restart process



NEM operation: Essential Power System Services



With present operational toolkit, need to maintain a minimum number of synchronous generating units online at all times to provide essential system services:

- System strength, inertia, frequency control, voltage control

These units need to operate above minimum loading levels

Operational demand is projected to fall below minimum thresholds by 2024 – 2026 for the entire NEM mainland under system normal conditions

Will reach thresholds sooner during periods with line outages, regions operating as an island, or extreme conditions (e.g. bushfires, storms, explosions, etc.)

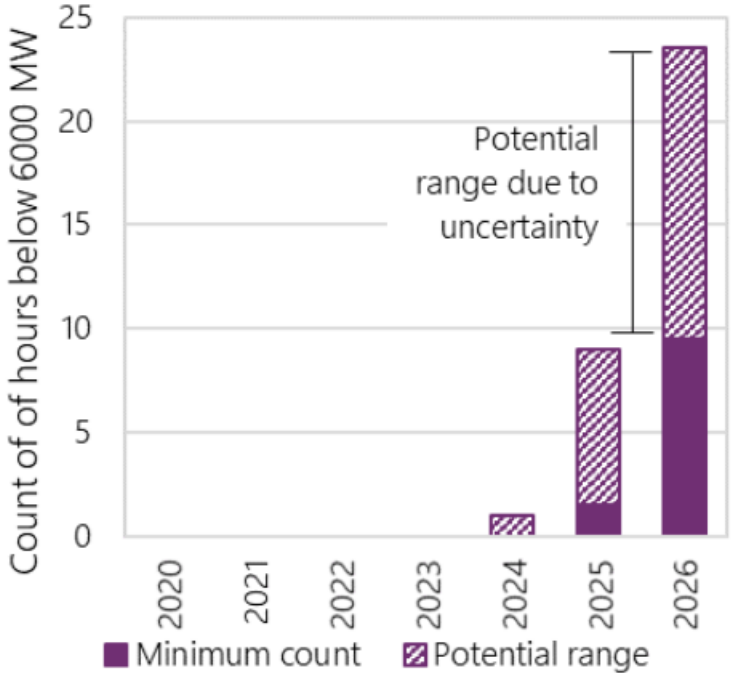
AEMO, ESOO 2021, Section 6.1, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2021/2021-nem-esoo.pdf?la=en&hash=D53ED10E2E0D452C79F97812BDD926ED

Incidence below thresholds

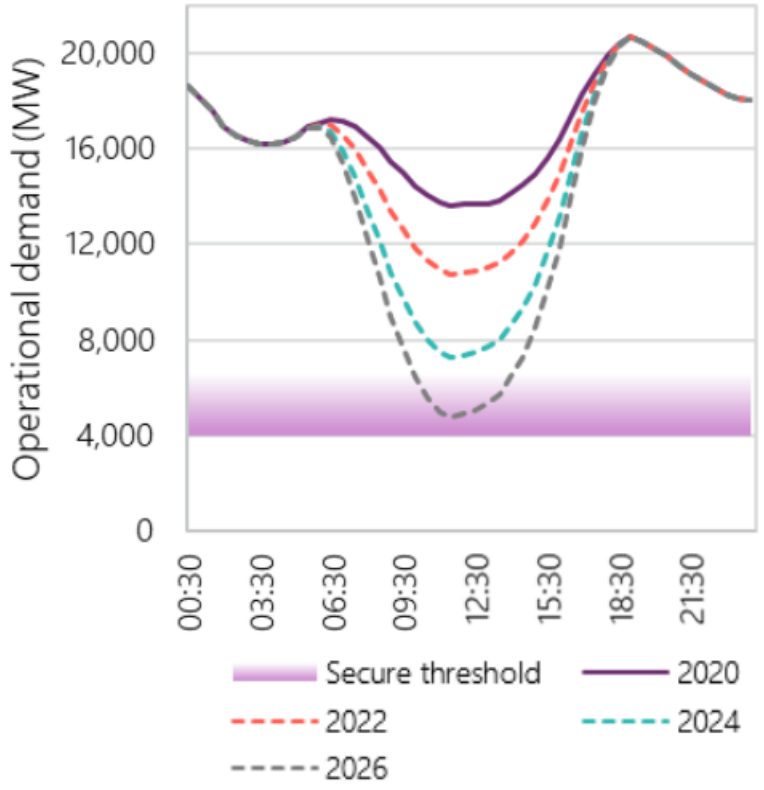
- Demand below thresholds occurs very rarely
- "Perfect Storm" conditions
  - Clear skies
  - Mild weather
  - Low demand (e.g. public holidays, weekends)

Forecast incidence of operational demand below secure thresholds (NEM mainland)

(a) Indicative range of operational demand below 6,000 MW across central scenario



(b) Example minimum demand day, Central projection 90% POE

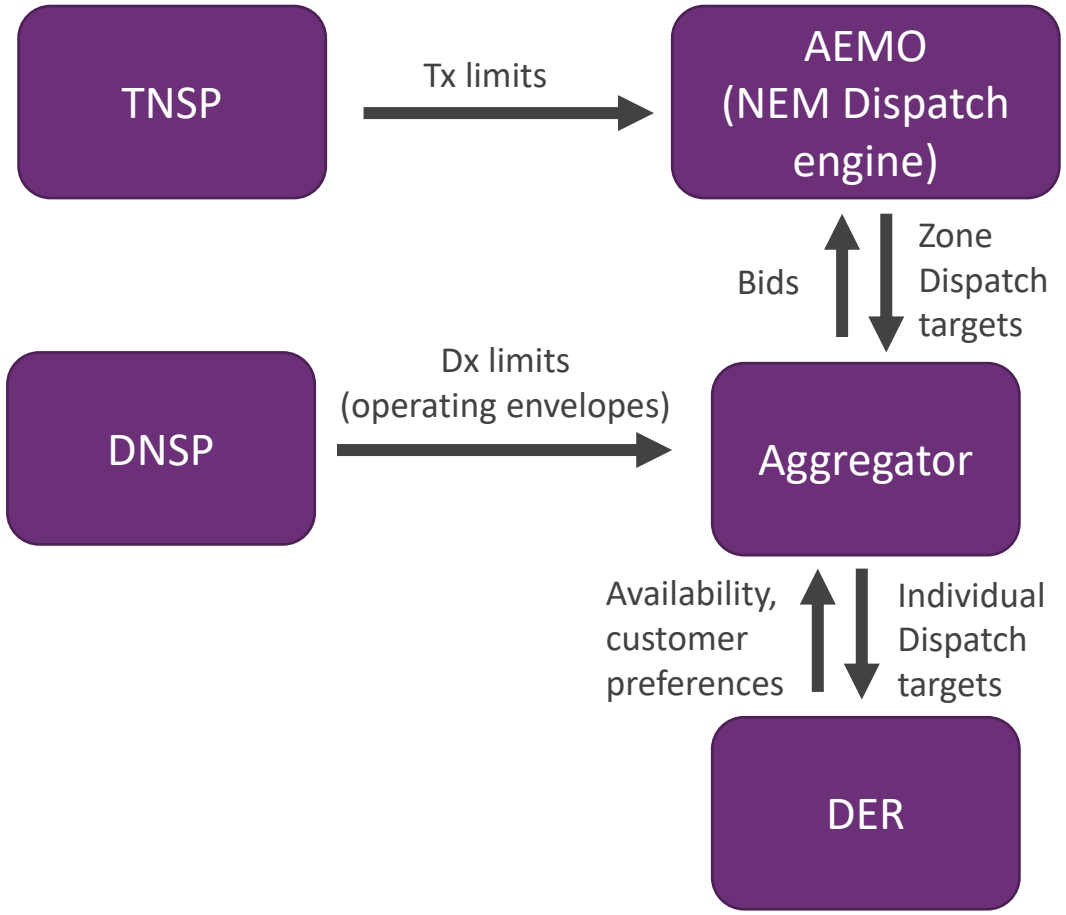


Multiple simulations with varying POE were run to determine the number of hours in which demand fell below 6,000 MW. This represents a wider spread of possibilities than used in Figure 24.

AEMO, ESOO 2021, Section 6.1, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2021/2021-nem-esoo.pdf?la=en&hash=D53ED10E2E0D452C79F97812BDD926ED

DER Dispatch Integration

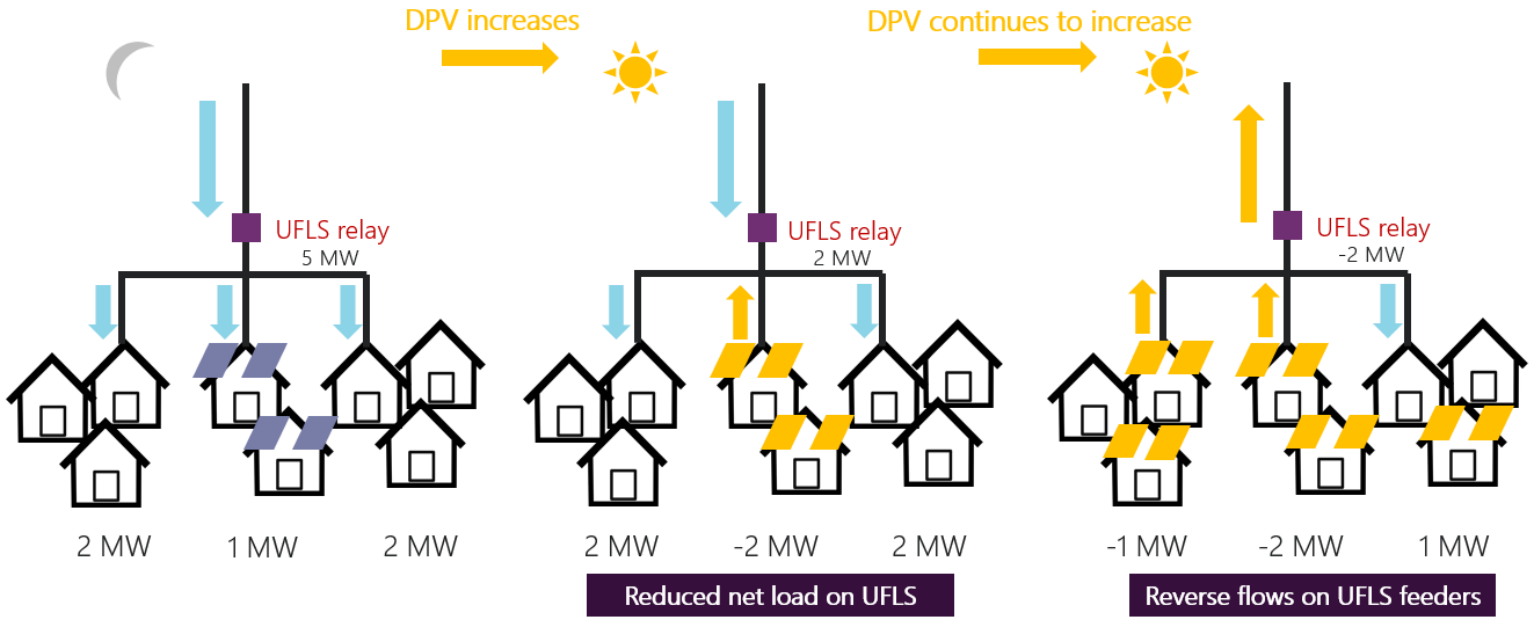
- Long term: Integrate DER into automated dispatch systems



- Formulating constraints incorporating DER (sub-regional zones?)
- Registrations in zones? Scaling over time?
- Device vs site bids/targets? Net or gross?
- Real-time telemetry?

Under Frequency Load Shedding

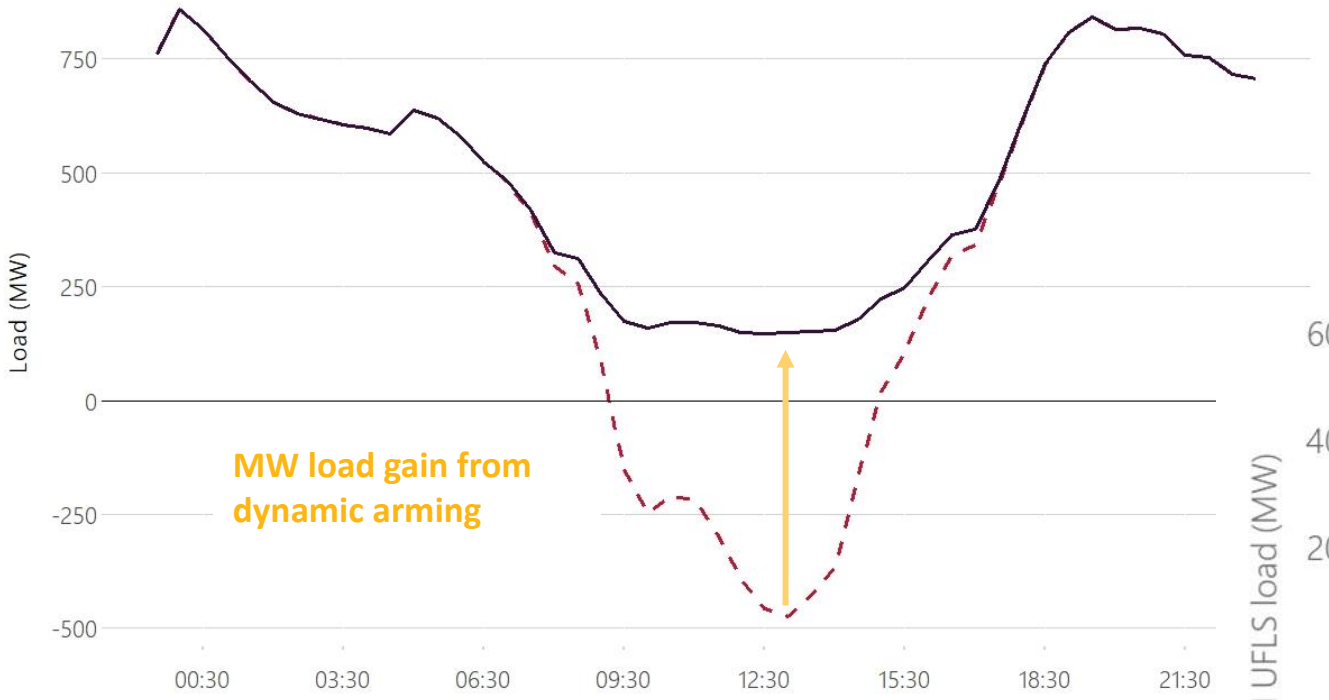
- UFLS is the “safety net”, designed to arrest severe under-frequency events
- Controlled disconnection of load in less than a second, to rebalance a large supply-demand imbalance
- Challenges identified:
  1. Reducing net load reduces UFLS effectiveness
  2. Reverse flows cause UFLS to operate in reverse, exacerbating a frequency decline
  3. Distributed PV disconnection exacerbates frequency decline



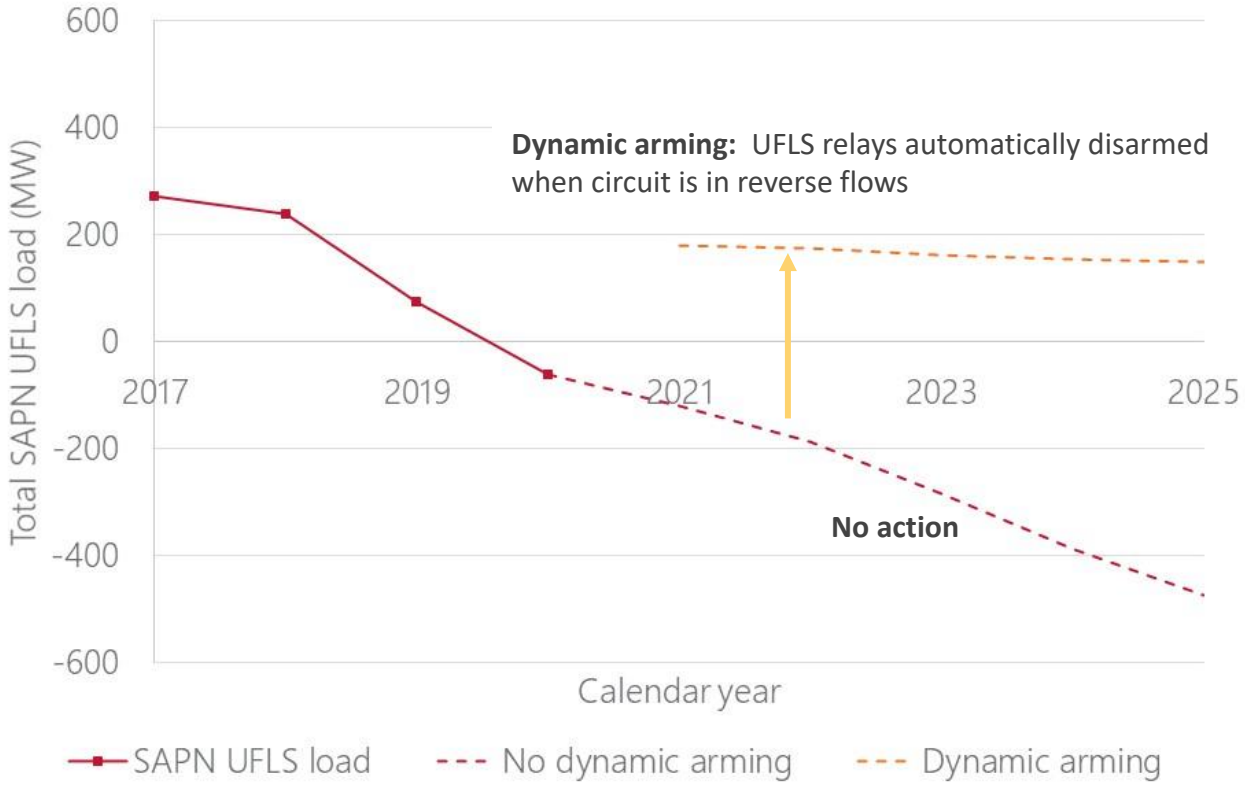
Under Frequency Load Shedding

- Total UFLS load in SA reached **-110 MW** (-152 MW on distribution network) on 21/11/2021
- Should be ~800 to 1,200 MW
- Significant reverse flows

Dynamic arming



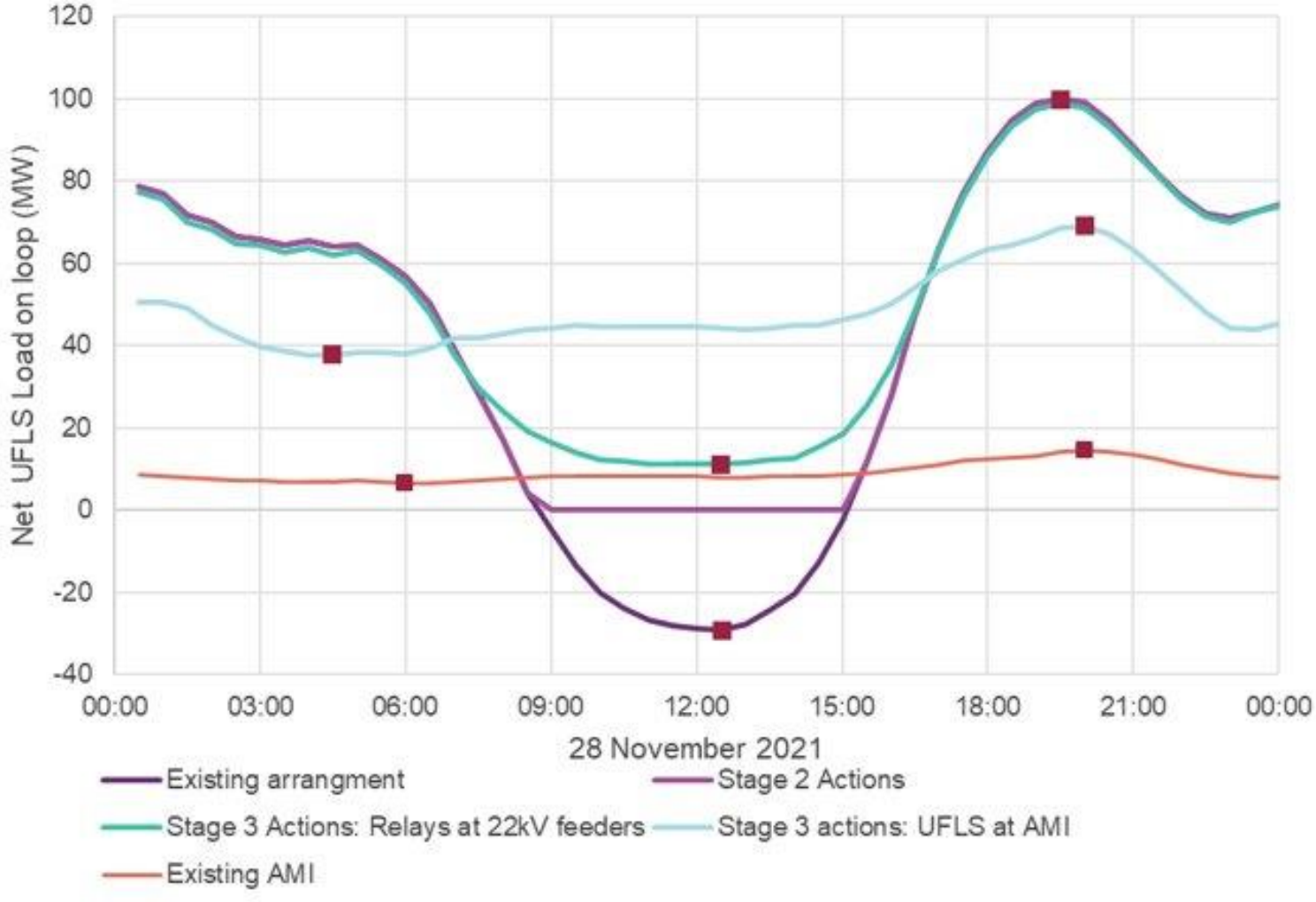
- Disable UFLS relay when circuit is operating in reverse flows



AEMO (May 2021) South Australian Under Frequency Load Shedding – Dynamic Arming, https://aemo.com.au/-/media/files/initiatives/der/2021/south-australian-ufls-dynamic-arming.pdf?la=en&hash=C82E09BBF2A112ED014F3436A18D836C

Smart Meters for UFLS?

- Exploring options for UFLS at the customer premise (utilising Advanced Metering Infrastructure)



How much Emergency Under Frequency Response is required?

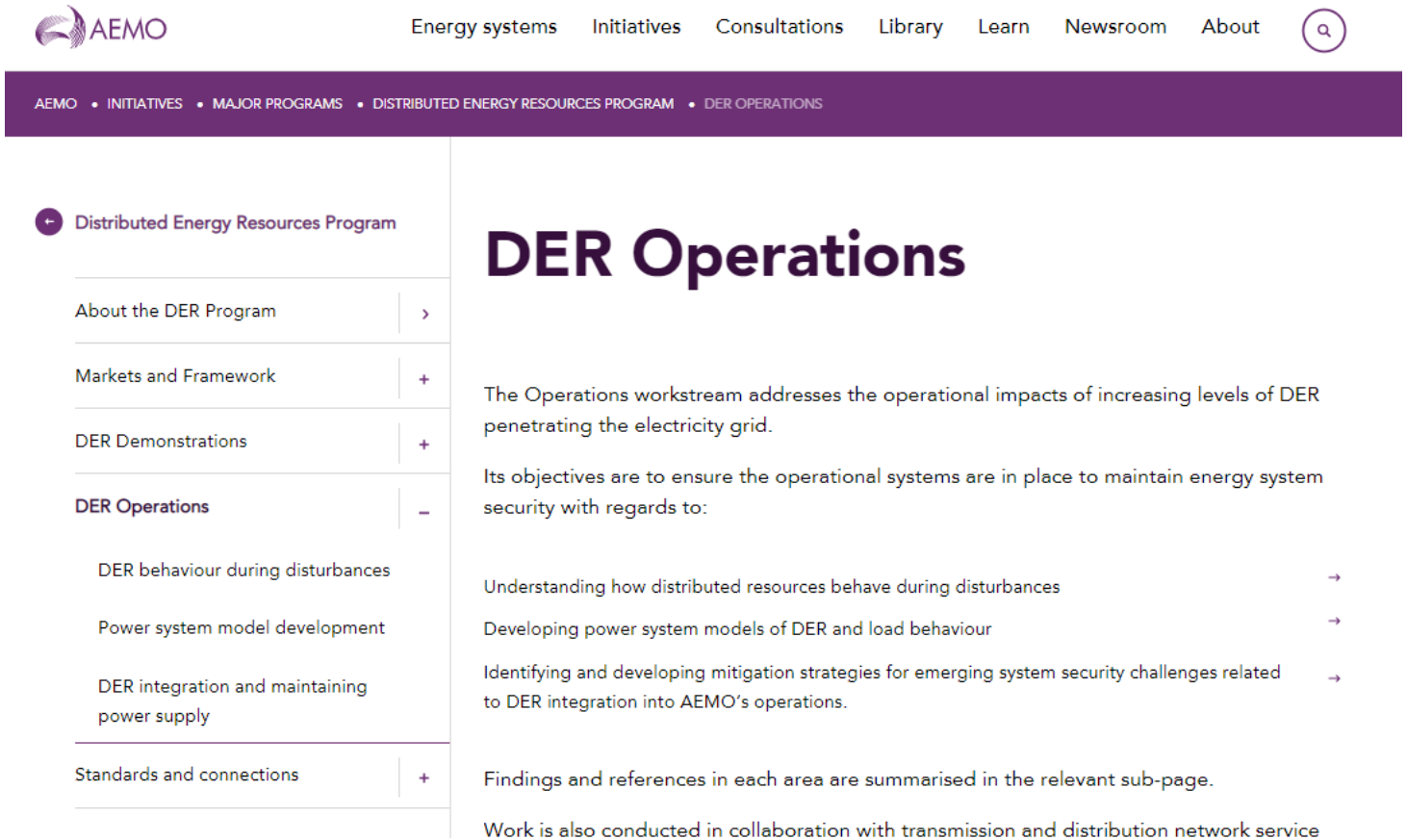
- What contingency events are we managing in very low demand periods?
  - In low demand periods: Minimal imports and few large units online?
- If DPV shake-off is part of the contingency, how does UFLS respond?
- Cybersecurity events?
- Influence of large BESS?

Ongoing work program

- Aim to enable NEM and SWIS to operate with 100% of energy supplied by DER
- Remove barriers to DER growth
- Essential to identify and address technical challenges early
- Very difficult to remediate if action is too late

For further information

- Reports available:
  - https://aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-der-program/operations



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