Board Paper

QUESTION: With our power system moving to increasing volumes of intermittent and asynchronous generation resources – is our market design capable of meeting this challenge? Is our market working or are we in fact missing markets for things like fast frequency, system strength and inertia?

AUTHORS: Sebin Jose (Wilson Transformer), Dan Tang (AEMO), Lucinda Walker (Clean Technology Partners), Phillip Wong (TransGrid), Hosoo Yoon (ElectraNet)

EXECUTIVE SUMMARY

The seismic transition from traditional synchronous to inverter-based resources (IBR), for example wind and solar PV generation, poses some critical challenges to network operators, market participants, and end customers. This is exacerbated further by the shift from traditionally, a handful of large capacity generators to smaller but numerous distributed energy resources (DER) in the National Electricity Market (NEM). Some of the challenges with the power system transition are:

- Voltage and frequency control with low level of system strength and inertia;
- System reliability issues with variability and uncertainty of intermittent generation; and
- System security issues with increasing penetration from DER.

The current NEM can be categorised as Energy Wholesale Market and Market and Non-Market Ancillary Service. Considering these new challenges arising as a result of the transition towards renewable generation, there is a need to introduce new market mechanisms and/or services to incentivise generators and customers alike to support system strength and inertia in new ways.

The Australian Energy Market Commission (AEMC) has made a final rule determination for the efficient provision of system strength. The final rule determination represents an evolution of the current system strength framework to meet new system strength requirements. Furthermore, the AEMC has also published a final rule determination to introduce a new frequency control ancillary services (FCAS) to help maintain system frequency and keep the future electricity system secure.

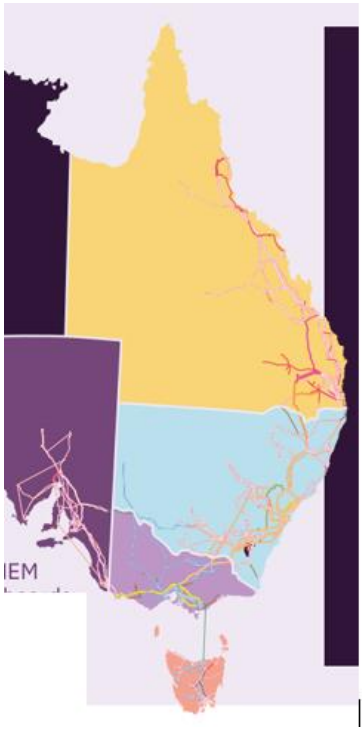
Further to the above-mentioned rule changes, there are also initiatives currently under consultation by the AEMC, which aim to address the issues raised regarding system strength and the retiring of traditional synchronous machines which traditionally provided system inertia. These include Operational security mechanism, Operating reserve market, and a Capacity mechanism suggested by Energy Security Board.

In addition, we have highlighted a 'new' potential market to address the issues surrounding times where the network experiences lower than minimum demand on their networks due to distributed behind-the-meter solar PV. This new market, termed 'Small Generation Management Aggregators' would leverage the existing 'Small Generator Aggregator' in the NEM rules, along with the current implementation of Demand Response (DR) agreements to allow Financially Responsible Market Participants (FRMP) to aggregate behind-the-metre DER for curtailment management purposes. The generator and/or the aggregator would be incentivised through rewards for reduced generation when called upon during times of minimum demand.

1 Introduction

1.1 Electricity, Key Consumption Statistics

Electricity is undoubtedly an integral part of our daily lives. It permeates our homes, work places, with the invisible electrons powering the myriad of appliances, from white goods, computers, electronics, to life saving inventions and transportations. Electrification transforms our lives to be better in every way, thanks to the dedication of the hundreds of thousands of people in the industry. Access to affordable and reliable electricity is as easy as 'flicking the switch'.

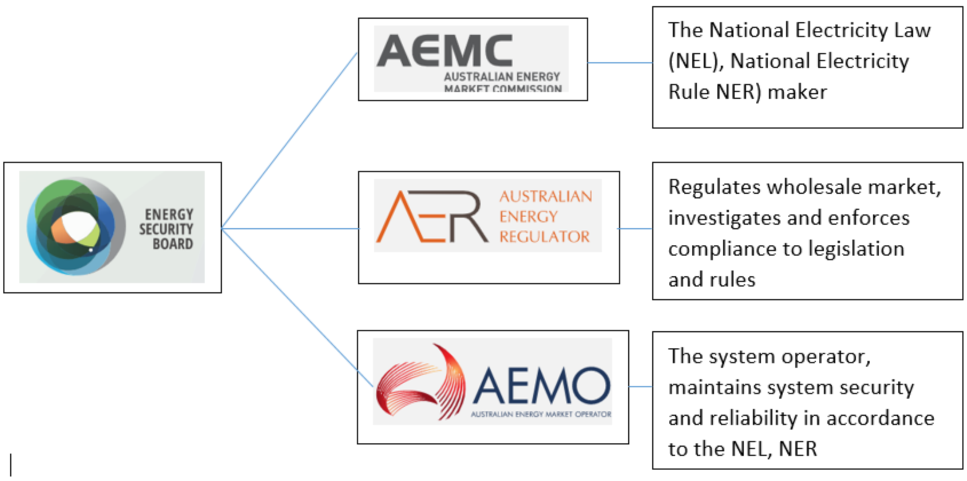


'In the Australian context, the National Electricity Market (NEM) operates on one of the world's longest interconnected power *systems. From Port Douglas in Queensland to Port Lincoln in South Australia and across the Bass Strait to Tasmania - a distance of around 5,000 km' (AEMO, 2022).*

The NEM's transmission network carries power from electricity generators to large industrial energy users and local electricity distributors across the five regions. These assets are owned and operated by state governments, or private businesses.

This precious commodity underpins the nation's prosperity, the lives as we know it and hence, operating the NEM securely and reliably in an affordable manner is paramount.

'In 2021, Australia's NEM supplies approximately 204 TWh of electricity to 10.5 million customers.



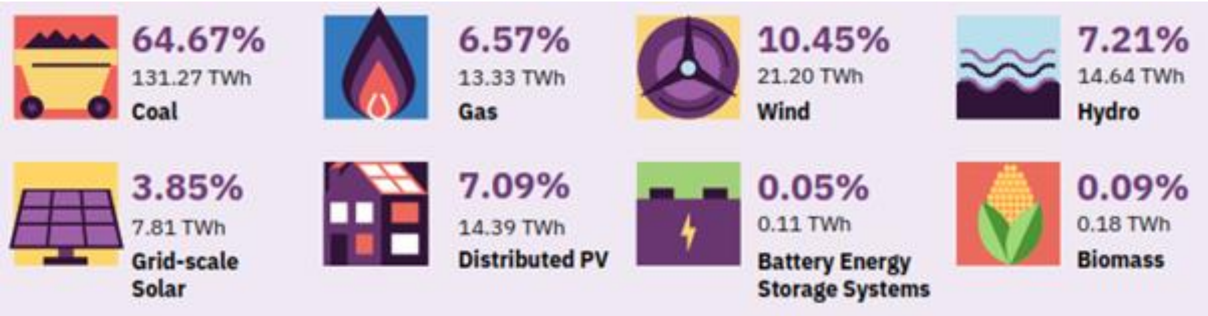
Please note the definitions:

System Security - that the system continues operating within defined technical limits, even if a major power system element (such as a generator or interconnector) is unexpectedly disconnected.

System Reliability - that the capacity to produce and transport electricity will be sufficient to meet the demand for electricity.

1.2 Energy Transition

The 2021 annual generation by fuel type is as per the figure below with approximately 30% generation derived from renewable energy sources, a tremendous uplift from 6% in 2010. Existing growth trajectory indicating the possibility of 100% renewables generation availability, to meet customer demand by 2025.



The transition from traditional synchronous generation with spinning mass to asynchronous generation with inverter-based resources (for example, wind and solar) poses some unique challenges to market participants, operators and end customers. This is exacerbated further by the shift from traditionally, a handful of large capacity generators to smaller but numerous DER.

This board paper will be delving further into some of the power system security and reliability challenges that are directly attributable to the transition as mentioned afore:

- Voltage and frequency control with low level of system strength and inertia;
- System reliability issues with variability and uncertainty of intermittent generation; and
- System security issues with increasing penetration from DER.

This board paper will investigate the mechanisms that are currently available (committed and proposed) to address the key challenges:

- Fast Frequency Response Market Ancillary Service;
- Efficient Management of System Strength on the Power System;
- Operational Security Mechanism;
- Operating Reserve Market;
- Capacity Mechanism; and
- DER Implementation Plan.

This paper will also present the following insights to further alleviate the energy transition challenges:

- Market for System Strength and Inertia;
- Capacity Mechanism for Reliability; and
- Small Generation Management Aggregators (Behind-the-Meter Flexible DER).

2 Current Markets

2.1 Energy Wholesale Market

AEMO operates the NEM electricity wholesale market where electricity is sold by generators and bought by retailers. The electricity is then on-sold by the retailers to residential or large-scale customers.

The NEM comprises more than 504 registered participants which includes market generators, TNSPs, DNSPs and market customers. $11.5 billion was traded in NEM in the financial year 2020-2021 and the NEM supplies roughly 10.7 million customers. The NEM has a total electricity generating capacity of 65,252 MW.

2.2 Non-Market Ancillary Services

Services that are essential to the management of power system security, facilitate orderly trading in electricity and ensure that electricity supplies are of acceptable quality.

The various ancillary services that are relevant are:

- Frequency Control Ancillary Services (FCAS);
- Network Loadin Control Ancillary Services (NLCAS);
- System Restart Ancillary Services (SRAS);
- Network Support & Control Ancillary Services (NSCAS); and
- Transient and Oscillatory Stability Ancillary Service (TOSAS);

2.2.1 Frequency Control Ancillary Services

AEMO employs two types of market ancillary services to manage system frequency during normal operational conditions and following contingency events:

- Regulation services – available to Registered participants only; and
- Contingency Services.

2.2.2.1 Regulation services

Regulation services are enabled to manage minor supply-demand imbalances within the normal operating frequency band following small deviations in the demand/generation balance within the five-minute dispatch interval. There are two Regulation FCAS markets:

- Regulating raise/lower services.

Regulation services are centrally controlled by AEMO. AEMO's Automatic Generation Control (AGC) system allows AEMO to continually monitor the frequency and time error. It also sends control signals through the supervisory control and data acquisition (SCADA) systems to Ancillary Service Facilities enabled to provide regulation services so frequency is maintained within the normal operating frequency band of 49.85 Hz to 50.15 Hz.

2.2 2.2 Contingency Services

Contingency services are enabled to ensure the power system can arrest and recover from material frequency deviations that might arise from larger supply-demand imbalances.

There are six Contingency FCAS markets:

- fast raise/lower services;
- slow raise/lower service; and

- delayed raise/lower service.

2.2.2 Network Loading Control Ancillary Services

Network Loading Control Ancillary Services are used by AEMO to control the flow on inter-connectors to within short-term limits. In order to achieve this, AEMO reduces electricity flow through specific interconnectors by increasing or decreasing generation in the relevant regions. This service can be controlled via the AGC signal, for registered and scheduled generators.

2.2.3 System Restart Ancillary Services

An SRAS is required to deliver its contracted service, when requested by AEMO, in response to a system restart or major system disturbance. The reporting criteria to be used for system restart ancillary service is the dispatch of the contracted service in line with its contract requirements following a black system or major system disturbance condition occurring.

2.2.4 Network Support & Control Ancillary Services

NSCAS are non-market ancillary services (NMAS) procured to control active and reactive power flow into or out of an electricity transmission network, to address the following NSCAS needs:

- Maintain power system security and reliability of supply of the transmission network in accordance with the power system security standards and the reliability standard.
- Maintain or increase power transfer capability of the transmission network to maximise the present value of net economic benefit to all those who produce, consume or transport electricity in the market.

2.2.5 Transient & Oscillatory Stability Ancillary Services

Transient and Oscillatory Stability Ancillary Services control and fast-regulate the network voltage, increase the inertia of rotating mass connected to the power system. TOSAS can also act to rapidly increase/reduce load connected to the power system. When faults such as short circuits or malfunctioning equipment occur, a sharp transient "spike" in power flows can result, and damage Network equipment. Equipment capable of providing TOSAS include:

- Synchronous Generators, Static VAR Compensators, and generators – with the ability to provide ‘fast regulating services’
- Power System Stabilisers;
- Inertia Support services; and
- Battery Energy Storage Systems also have the ability to provide TOSAS services through ‘synthetic inertia.’

3 Challenges

3.1 Low System Strength and Inertia

In the power system, system strength is the ability to maintain and restore a correct voltage waveform during and after a fault event. Inertia is a force of any physical object to resist any change in its velocity. In power system, system inertia is the ability to slow down the rate of frequency changes when a disturbance occurs.

As the NEM moves towards asynchronous generation resources, our power system is facing a major challenge in terms of power system strength and inertia since they are mainly provided by synchronous machines. With low system strength, our power system will exhibit undesirable performance such as undamped voltage and power oscillations. With low system inertia, our power system will be threatened by a rapid frequency change when a major disturbance occurs. This may require load shedding or generation shedding. There is no current market service relating to system strength and inertia in the NEM as they were provided for 'free' by traditional synchronous generators. To address the challenges described above, the missing market services will need to be introduced to the NEM.

3.2 Reliability

In a power system, reliability is the capability to produce and transport electricity to sufficiently supply customer demand. Reliability can be achieved through a combination of generation, network capacity, and demand response.

As the power system has transitioned to variable renewable generation, it has become more difficult to ensure that there is sufficient generation to serve demand at all times. There is a need for fast, dispatchable generation to provide firming for the intermittent renewable generation. This firming capacity is not currently being valued in the energy market.

3.3 High Penetration of DER

The Energy Security Board (ESB) has raised in their ‘Effective integration of DER and flexible demand’ work, the risks of increased DER on the ongoing reliability and security of the NEM. A key risk is that of demand dipping below the minimum demand levels set in different parts of the network. Minimum demand is set based on minimum system strength requirements, going below these levels is a risk to system security due to synchronous generation requirements, and to balance load and generation, ultimately to prevent system shutdown.

Current mitigation actions such as Under Frequency Load Shedding (UFLS) are no longer working as effectively as they used to, due to many residential and C&I customers now being ‘mini’ generators as well as ‘mini’ loads. With the increasing risks facing the NEM in responding to these risks, future markets may be required to manage this network instability.

4 Committed and Proposed Markets

4.1 Fast Frequency Response Market Ancillary Service (FFR MAS)[1]

On 15 July 2021, AEMC published a final determination and a final rule to introduce a new market ancillary service to help control system frequency and keep the future electricity system secure. The final rule for the new Fast Frequency Response (FFR) market ancillary service introduced two new market ancillary services into the NER for:

- the very fast raise service (less than 2 second Raise): less than 2 second response for frequency recovery following a major frequency drop.
- the very fast lower service (less than 2 second Lower): less than 2 second response for frequency recovery following a major frequency rise.

4.2 Efficient Management of System Strength on the Power System[2]

On 21 October 2021, the AEMC made a final rule determination for the efficient provision of system strength. The final rule determination represents an evolution of the current system strength framework to meet new system strength requirements. The Amending Rule will be implemented in AEMO instruments including the System Strength Requirements Methodology (SSRM) and System Strength Impact Assessment Guidelines (SSIAG). AEMO is now initiating consultation on amendments to the SSRM and SSIAG.

4.3 Operational Security Mechanism[3]

On 19 November 2019, Hydro Tasmania submitted a rule change request proposing to create a market for 'synchronous services'. On 4 June 2020, the AEMC received a rule change request from Delta Electricity proposing to introduce a capacity commitment mechanism for system security and reliability services. The AEMC consolidated the two requests under one consideration called 'Operational security mechanism'. On 9 September 2021, the AEMC published a directions paper proposing approaches of scheduling resources to maintain power system security:

- Market ancillary services (MAS): procurement of system services in the pre-dispatch engine to explicitly value them.
- Non-market ancillary services (NMAS): procurement of system services through contracts which would be scheduled through an explicit optimisation approach.

4.4 Operating Reserve Market

On 2 July 2020, the AEMC initiated a rule change request from Infigen Energy and Delta Electricity. The proposal seeks to introduce an operating reserve to help respond to unexpected changes in supply and demand[4].

In addition to the proposal, AEMC recommend the following new market services[5]:

- Co-optimised operating reserve market: A reserve market co-optimised with the current energy and FCAS markets to produce energy in the next dispatch interval.

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[1] Fast frequency response market ancillary service - Final Determination (aemc.gov.au)

[2] ERC0300: System strength final determination - 21 Oct 2021 (aemc.gov.au)

[3] https://www.aemc.gov.au/rule-changes/operational-security-mechanism

[4] https://www.aemc.gov.au/rule-changes/operating-reserve-market

[5] AEMC, Reserve services in the National Information Sheet

- Co-optimised availability market: A reserve market co-optimised with the current energy and FCAS markets to provide energy in the dispatch interval 30-minutes ahead.
- Callable operating reserve market: A reserve market to provide energy in a later dispatch interval proposed by Infigen Energy.
- Ramping commitment market: A reserve market producing 30-minute ramping services using current FCAS market proposed by Delta Electricity.

4.5 Generation Capacity Mechanism

In the Post-2025 Market Design Directions Paper (Jan, 2021), the ESB has recommended a capacity mechanism to value energy availability. This complementary market intends to place a value on generators being available for firming during times where demand could exceed supply in the wholesale electricity market. The objective is to create a clear price signal for investment in dispatchable capacity to maintain reliability and minimise cost as the power system moves towards increasing volumes of intermittent generation resources. This mechanism is also expected to improve public confidence that reliability will be maintained in the energy transition and reduce government interventions. The ESB will develop the detailed design of the capacity mechanism by the end of 2022 for agreement by Ministers in mid-2023.

4.6 DER Implementation Plan

The ESB's post-2025 Market Design Directions Paper (Jan, 2021) has suggested that demand-side participation is required to manage the ongoing risks in a way that also rewards, where possible, customers for flexibility and participation. This paper suggests the following points are required in developing a new market mechanism, and as part of its 'DER Implementation Plan:'

- Clear signals to behind-the-meter generators to reduce or increase generation;
- Flexible management of solar PV & battery generation;
- A way forward to reduce the impacts of DER on falling minimum demand.
- Visibility and tools needed to continue to operate a safe, secure and reliable system.

It is also stated that as part of the DER Implementation Plan, the networks are to be able to 'accommodate the continued uptake of DER and two-way flows and are able to manage the security of the network in a cost-effective way.'

5 Insights

5.1 Markets for System Strength and Inertia

There are several rule changes (determined and under consideration) aimed at addressing the challenge of low system strength and inertia as the power system transitions to increasing volumes of asynchronous generation. The FFR MAS for frequency response within 2 seconds helps to address the gap in the existing market for frequency response in the 0- to 6-second timeframe. However, it does not directly incentivise frequency response in a millisecond timeframe, which has been traditionally provided through synchronous inertia. Depending on the speed of response provided by participants in the FFR MAS, there may still be a gap in the market to address the challenge of falling inertia in the power system. It is noted that, using Synthetic Inertia Virtual Machine Mode (SIVMM), the Dalrymple BESS response from 0 to 100% (discharge) was 100 ms to arrest frequency rise when the Heywood interconnector between SA Victoria was tripped in November 2019.

Given the low system strength challenges stemming from the energy transition, rule changes to value system strength services are well worth considering. In the operational security mechanism rule change currently under consideration, the AEMC has proposed MAS and NMAS approaches. Since system strength is difficult to quantify and is highly locational, it is not conducive to an operational NEM-wide market solution. Regional/zone markets in the NEM are also not an optimal solution because there may not be enough participants to make the markets competitive. The AEMC has an initial preference for the NMAS approach. We agree that the NMAS approach is more appropriate and cost efficient than the MAS approach to procuring system services. It is worth noting that proper implementation of the 'efficient management of system strength in the power system' rule determination will reduce the need and value of a potential future market approach to addressing inertia and system strength.

5.2 Generation Capacity Mechanism for Reliability

Generators are already sufficiently incentivised to build capacity indirectly through the wholesale electricity market. In certain parts, the network already has more capacity than is consumed, due to available generation often being constrained. As described above in Section 4.5, the ESB has proposed introducing a capacity mechanism to result in additional capacity connecting to the network – some of which will help improve reliability, but some will ultimately be constrained and not contribute to reliability.

Upon review of the ESB's recommendation, we have determined that a capacity mechanism is a solution that does not target the real system problems that impact reliability in the transition from centralised dispatchable generation to decentralised intermittent generation. Instead, it might be more effective and efficient to have stronger locational pricing signals, incentivise Battery Energy Storage Systems in locations that will free up network capacity, or develop the transmission/distribution network to alleviate constraints.

5.3 Small Generation Management Aggregators (Behind-the-Metre Flexible DER)

Under current arrangements, retailers and NSPs alike are offering their customers Demand Response (DR) contracts under four (4) possible streams: Wholesale Demand Response, Energy Demand Response, Ancillary Services Demand Response, and Network Demand Response. These DR agreements allow the retailers and NSPs to reward eligible customers via payments by providing different services.

We propose an additional market could be implemented in a similar way as part of contracts for small-scale behind-the-meter DER flexible '**Small Generation Management Aggregators (SGMA)**.' It is proposed that the same mechanisms currently in place for aggregators of small-scale demand response contracts with residential and C&I customers could be implemented to dynamically manage multiple Rooftop PV Generators at times when generation exceeds minimum demand in specific parts of the network.

Ideal aggregators for this proposed market would be Retailers, Small Generation Aggregators (SGA) currently providing aggregation of non-registered 'small generators' to allow participation in FCAS markets via a Financially Responsible Market Participant (FRMP), Retailers and other organisations who offer DR contracts/arrangements with their behind-the-meter customers, allowing the customers to become market participants via the third-party aggregator, and to provide flexible curtailment management of DER. This would allow aggregators to dynamically manage DER for NSP's at times to enable simultaneous curtailment management of multiple small generators within the same network area experiencing lower than minimum demand.

Note that software upgrades, and/or devices a may be required to enable aggregation and third-party management.

Market mechanisms could be implemented similarly to that of Demand Response programs, which reward generators and/or '**Small Generation Management Aggregators**' for participating and contributing to System Strength by means of flexible curtailment management.

6 Conclusion

As the NEM moves towards more asynchronous generation resources, our power system is facing a major challenge in terms of power system strength and inertia. With new low system inertia, our power system can be affected by rapid frequency changes when a major disturbance occurs, therefore risking security and reliability of the network.

Current actions such as Under Frequency Load Shedding (UFLS) are no longer working as effectively as they had in the past to mitigate the system issues. New markets to incentivise generators to provide system inertia and system strength could facilitate a stronger grid into the future. Emerging markets, such as Fast Frequency Response (1-2 second raise/lower services), along with 'Small Generation Management Aggregators' to assist in preventing the electricity network from experiencing below-minimum demand levels, are some ways the NEM will be capable of sustaining a reliable and strong network into the future.

In the ideal scenario, the electricity markets are designed to provide reliable electricity at least cost to consumers. The best market designs achieve this via short-run efficiency (making the best use of existing resources) and long-run efficiency (promoting efficient investment in new resources). Effectively the market must send the right price signals to motivate efficient generation and investment in resources to alleviate challenges over time. This challenging predicament is borne from the complexity of engineering and economic problems that must be solved.

Past history has shown that allowing the market to dictate the outcome has its advantages and disadvantages. The advantages encapsulate: less 'red tape' (and administrative costs), encouragement of innovation; fostering of competition; and customer driven choices ensures only the product that meets needs at a reasonable price point would survive. On the contrary there are also disadvantages of a market driven system: profit driven motive reduces the availability of choices; the erosion of safety, environmental and ethical standards in pursuit of profitability; and market failure from the pursuit of short-term profits over slow and steady gains.

This board paper has presented the challenges that lie ahead in the pursuit of transition to asynchronous renewable energy resources, the current market as it stands, the committed and proposed market. There are certainly more improvements that can be made to ensure a more secure, reliable and affordable market.