IMPLICATIONS OF A GREEN FUTURE

ABSTRACT

Australia's electricity system is undergoing unprecedented changes arising from the proliferation of renewable energy generation. Our grid is not designed to cope with such rapid energy transition and is frequently being pushed to its limits, threatening the future of our energy security. What are the problems caused by renewables? How are they threatening system operations? What are we doing to fix these problems? This paper answers these basic questions with an aim to depict a general direction on where our electricity system is heading, and to provide a basis for further investment analysis.

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EXECUTIVE SUMMARY

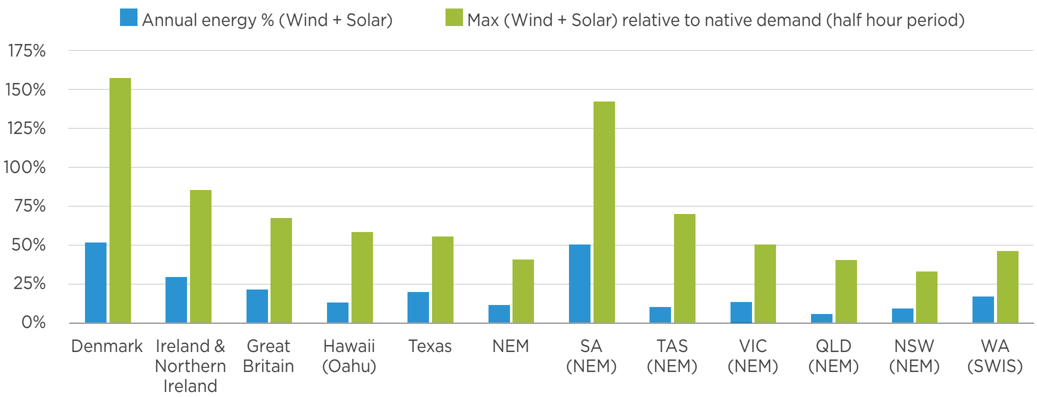
Australia's electricity system is undergoing unprecedented changes as a result of increasing renewable energy generation. The transition is happening very rapidly, with South Australia and other parts of the National Energy Market (NEM) already reaching the highest level of renewable penetration in the world. While such rapid transition is positive for global decarbonization efforts, it frequently pushes our electricity grid to its limits, threatening the future reliability and security of our energy system. Recently, market interventions performed by the Australian Energy Market Operator (AEMO) has increased dramatically; from 15 times in 2016/2017 to 229 times in 2019/2020[1]. Such frequent interventions not only threaten the functioning of the NEM, it also distorts market prices, with consumers ultimately footing the bill.

Changes are coming: our existing electricity system is not designed to cope with current renewables generation levels and requires a significant amount of network investments and reconfigurations in the next decade to accommodate this transition. As an investor in the utility sector, it is essential that we understand how this transition is going to affect our system and what major changes are likely to be undertaken in the future, so that ultimately, we can assess the investment implications for the major market participants under our coverage.

Given the scope, complexity, and evolving nature of this topic, we plan to assess these developments through a series of research. This paper is the first in the series with an aim to establish a basic understanding of what these threats are, what immediate actions are being undertaken by the regulators, and how these actions may affect the market participants in the near term. Whilst it is too early to draw any investment conclusions from this paper alone, it depicts a general direction on where we are heading and provides a basis for further analysis.

At a high level, we see the transmission network operators are clear winners from these changes. They will have an opportunity to significantly increase their regulated asset base and earn a higher revenue going forward. However, their ability to raise equity capital will depend on the attractiveness of the return on equity, which is set by the regulator and has been on a declining trend. Also, we could see a temporary decline in their credit profile during the capex phase of these investment, given the sheer size and duration of these capex projects.

FIGURE 1: PARTS OF AUSTRALIA HAS ONE OF THE HIGHEST INSTANTANEOUS PENETRATION OF WIND AND SOLAR GENERATION IN THE WORLD



Source: AEMO 2019

1 AEMO, Integrated Renewable Study, 2020

We believe standalone renewable projects could stand to lose further in the near term, given the number of rule changes introduced to deal with the imminent threats within NEM. Not only will output continue to be curtailed, initial capex and ongoing operating costs of renewables will increase to comply with new rules. However, as we decongest the network bottleneck and reconfigure our grid, the long-term outlook remains bright for renewable generation projects.

For large 'gentailers', existing conventional generators will play a critical role in providing system strength over the next decade. Gas-fired generators will benefit as their role becomes increasingly important to supplement the renewable generators. From this aspect, we think Origin is better positioned than AGL given Origin's greater exposure in gas-fired generation. Storage facility such as hydro-generation and battery will also play an increasingly important role in providing system inertia, hence a lot of investments are going into these technologies.

We also see an opportunity for distribution network providers to play a greater role in the NEM as we move away from centralised generation model to distributed generation model. There will be opportunities for greater investments into the network infrastructure and integration of roof-top PVs into the NEM. Both are likely to drive a higher regulated revenue for the distribution network providers in the long run.

However you look at it, changes are coming. Today's grid is not designed to cope with the rapid transition to renewables. A significant level of investment and reconfiguration is required over the next decade to accommodate it.

We will continue to review the sector to understand how this transition will impact the investment landscape for utilities and the major market participants under our coverage.

ABBREVIATIONS

AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
DER	Distributed energy resources
DNSP	Distribution Network Service Provider
DPV	Distributed photovoltaics
ESB	Energy Security Board
FCAS	Frequency Control Ancillary Services
ISP	Integrated System Plan
NEM	National Energy Market
PV	Photovoltaic
RIS	Renewable Integration Study
TNSP	Transmission Network Service Provider
VRE	Variable renewable energy

CHALLENGE 1:
REDUCED SYSTEM STRENGTH AND INERTIA

One of the key concerns with the increasing penetration of renewable generation is the weakening the system strength and system inertia of our electricity networks. This has resulted in much of the political debate on the importance of conventional energy source for the benefit of energy security.

WHAT IS SYSTEM STRENGTH AND INERTIA?

System strength measures system resilience; how well the system can maintain a stable **voltage** level when there is sudden change in supply or demand. **System Inertia** relates to the ability of the power system to resists changes in **frequency** caused by a sudden change in generation output and load levels. These two processes occur instantaneously and simultaneously and therefore often discussed together.

System strength is created by conventional forms of generation such as coal, gas, and hydro by their use of 'synchronous' generators, which are magnetically connected to the power system. When there is a sudden voltage disturbance on the power system, these generators will naturally respond in a manner that absorb these disturbances, thereby automatically stabilising network voltages. The ability to resist sudden changes in voltage magnitude comes from magnetic flux in the generator's core, a distinct process from the way in which the physical inertia of the synchronous generators resists changes in the power system frequency.

To illustrate simply: a conventional generator works by burning coal/gas to generate energy, which causes the rotation of a shaft or turbine to rotate and generate electricity. The speed at which it rotates determines the voltage within the system. Where a disruption causes a sudden change in the system, the shaft may speed up or slow down to absorb the change in voltage. **Inertia** is provided by the kinetic energy stored in the spinning component of the generator (e.g. shaft, turbine) while **system strength** is provided by the energy flow between the stator and rotor.

WHY DOES RENEWABLE GENERATION WEAKEN SYSTEM STRENGTH?

'Synchronisation' is a distinct feature of conventional generators where energy is transferred to electricity by a physical rotation movement. Renewable generation does not provide such synchronisation due to the use of inverters, which relies on algorithms to sense fluctuations within networks instead of a physical association with magnetic fields. Consequently, as more coal-fired plants are replaced by renewable sources, synchronous generators are decreasing which reduces overall system strength. Where a network location has low system strength, there is an increased risk of unplanned generator's tripping could cause cascade failures throughout the network.

In addition, system strength naturally diminishes with distance from synchronous generators. Given the vast scale and distances Australia's networks cover (see figure 2), there are many remote locations where system strength is naturally low.

Yet, many renewable projects are attracted to these locations where there is good wind or solar sources and low land costs. This has further exacerbated problems at several locations which are already experiencing weakness.

To exacerbate the issue, inverters may often interact with each other and causes more disturbances in the system. One inverter can respond in a fashion that disturbs the voltage waveform, and this disturbance will subsequently be seen by other inverters in an area and trigger a counter response by them. This can give rise to back-and-forth interactions between multiple inverters, which would ultimately result in the risk of ‘tripping’. Thus, even if a particular renewable project is inherently stable, there is a risk that it may induce systemic instability if more renewable projects are subsequently connected to the system.

WHAT ARE WE DOING ABOUT IT?

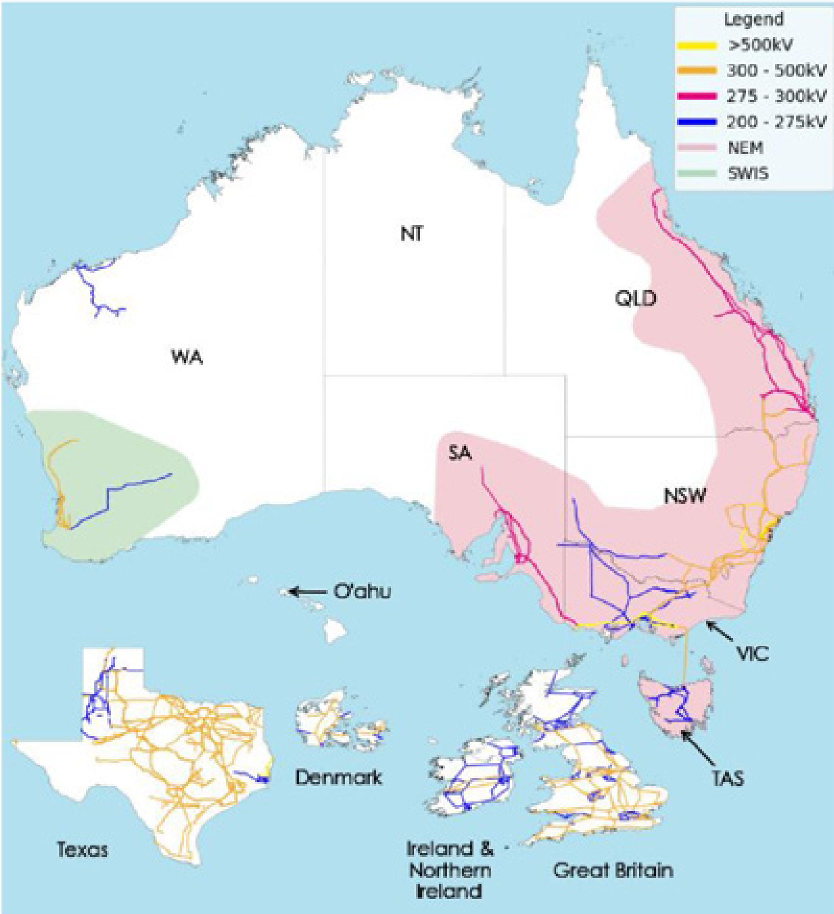
SYSTEM STRENGTH

In the near term, AEMO has already implemented several regulations in response to declining system strength:

i. **AEMO sets a minimum fault level[2] threshold at a number of key nodes throughout the NEM. Where the level of system strength is forecast to drop below AEMO’s thresholds, AEMO declares a system strength shortfall.**

ii. **The local Transmission Network Service Provider (TNSP) is required to a provide ‘system strength service’ to meet the minimum fault level if AEMO declares a shortfall.**

FIGURE 2: AUSTRALIA’S SYSTEM IS MUCH GREATER IN SCALE COMPARED TO ITS INTERNATIONAL PEERS



Source: AEMO 2019

iii. **Generators connecting in an area with low system strength conditions are required to demonstrate that they do not adversely impact system operation (the ‘do no harm’ rule).**

Each TNSP will be responsible for responding to a shortfall declared by AEMO within their area of responsibility; developing a suite of possible solutions to address the issue and determining the most cost-effective way to remediate the issues.

When a generator applies for a connection, they must go through a drawn-out connection assessment to ensure their inverters will operate stably and ‘do no harm’ to existing networks.

If it is determined that there is potential for ‘harm’, the generator must work with TNSP to modify their proposed connection or implement remedial measures that mitigate these risks. Such remediation measures may be in the form of a synchronous condenser or an operational scheme. The cost is to be borne by the generators.

2 Fault Level measures how much power would flow into a short circuit at that location, should one occur, and is often many multiples of the normal level of power flow. It is used as a proxy measure for system strength because the two are highly correlated. Network equipment must be capable of withstanding this level of flow before circuit breakers open and clear the fault.

Registered generators also have an ongoing obligation to demonstrate compliance with any system strength remediation scheme agreed with TNSP including implementation, maintenance and performance of the scheme.

The immediate impact from this rule change is that renewable project developers have been subjected to drawn out connection assessments, increased costs associated with system strength remediation, forced reduction in output or capacity utilisation; which leads to unanticipated shortfall in revenue. This is putting a lot of renewable generators economics at risk. Whereas TNSP on the other hand have an opportunity to earn additional revenue through the regulated process.

In the long term, AEMO's Integrated System Plan (2020) shows that significant amount of investments in transmission infrastructure is required for the next 20 years to accommodate the increasing penetration of utility-scale solar and wind generation, particularly in those remote and electrically weak parts of the NEM. This will create huge growth opportunities for TNSP; as such investment will increase their Regulated Asset Base (RAB) and therefore regulated revenue.

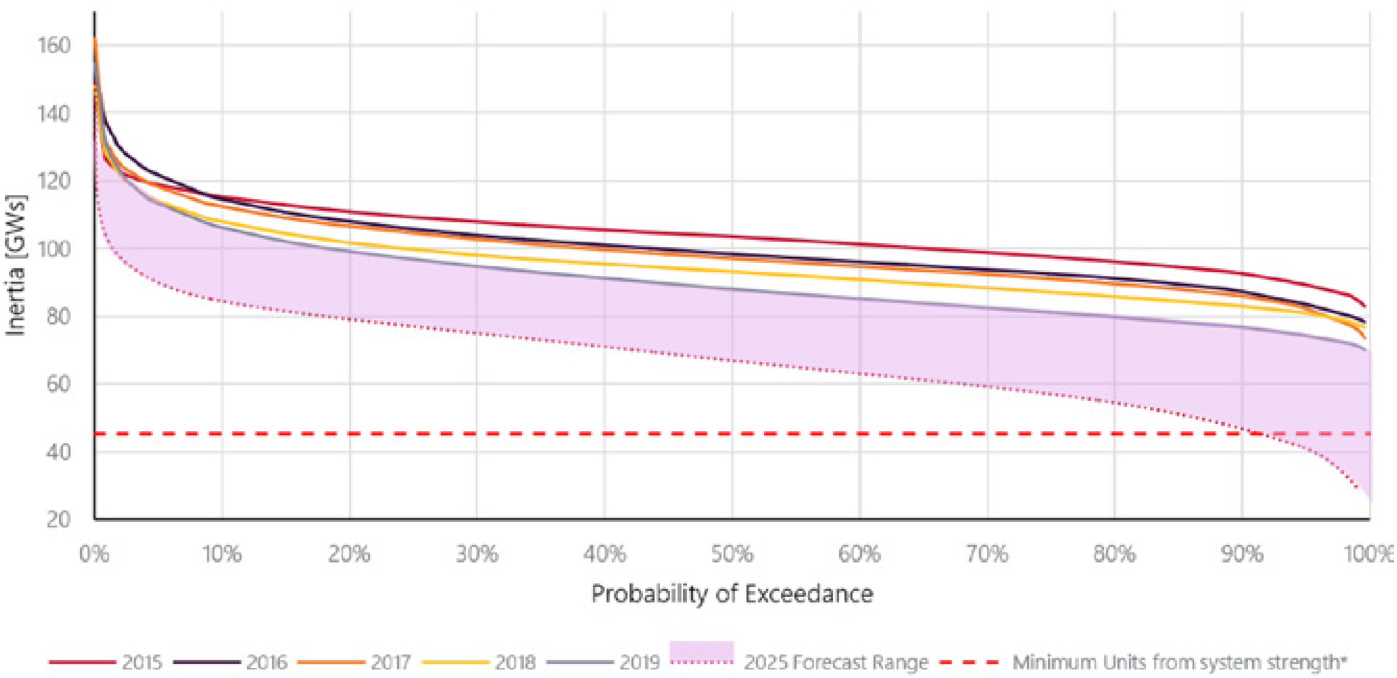
SYSTEM INERTIA

AEMO anticipates NEM inertia levels could drop by 35% by 2025 (see Figure 3). This will increase the required volume and/or speed of frequency sensitive generation reserves following a contingency event. AEMO has recommended the following staged approach to manage system frequency in anticipation of further declines in system Inertia.

i. **Implementing a Mandatory Primary Frequency Response (PFR) rule change, which requires universal PFR across the entire generation fleets.**

PFR is where a generator measures the local frequency and adjusts its active power output in response. PFR is automatic (not driven by a centralised system of control) and begins immediately after a frequency change beyond a specified level is detected. In Australia only certain conventional generators are required to have PFR enablement for large frequency changes, while there is no requirement for any PFR enablement for small frequency changes. Whereas in many other countries, it is mandatory that all conventional generators have PFR enablement.

FIGURE 3: HISTORICAL (ACTUAL) AND FUTURE RANGE (FORECAST) OF NEM INERTIA LEVEL



Source: AEMO 2020

In certain jurisdictions such as Ireland and Texas, it is also mandatory for renewable generators to have PFR enabled so that the grid operator can change the settings of PFR on the renewable plant in real time to make them more responsive to small frequency changes.

The Mandatory PFR rule change requires that all scheduled and semi-scheduled generators must operate in accordance with performance parameters set out in the Primary Frequency Response Requirements (PFRR), this includes all renewable generators such as wind and solar operators who participate in the NEM. AER is seeking this rule change because AEMO is increasingly unable to control frequency in the NEM due to reduced frequency responsiveness from generation, and the unavailability of tools to effectively control frequency on an ongoing basis.

There are concerns that renewable energy generators will be disproportionally penalised given the only available response to frequency fluctuation would be to reduce output, which cuts their revenues. In addition, the cost of upgrading equipment and control systems could run up to $1million for a generator to adapt to the new rule.

ii. **AEMO is also proposing a minimum inertia safety net for NEM and recommended a staged approach to operate at lower inertia within the system.**

AEMO will define minimum threshold level of inertia is required for each state. This minimum safety net will be progressively revised downwards as AEMO becomes more experienced in operating at new lower inertia levels.

This could mean that the retirement of conventional generators needs to be managed in a gradual manner to meet the minimum inertia level. Or, more synchronised condensers to be installed in conjunction with increasing renewable generators to provide the inertia required. Also, storage facilities such as pumped hydro, battery and hydrogen will play an increasingly important role in providing system inertia given their dispatchability and low emission.

CHALLENGE 2
INCREASING VARIABILITY AND UNCERTAINTY OF OUTPUT

AEMO manages system demand and supply by forecasts, and generation fleets are scheduled to cover the expected level of demand. The electricity system must have sufficient flexibility to maintain the demand and supply balances throughout all periods including those contingent events. The increase in renewable generation mix poses key challenges to how AEMO maintains the balance in the system due to:

1. Increased variability in both demand and supply, making it difficult for AEMO to forecast. This is driven by weather dependent utility-scale wind and solar affecting actual supply of energy while rooftop PV affecting actual demand.
2. Increased uncertainty in forecasts for weather driven renewable output, and aging conventional generation becoming less reliable. Variable events such as changes in wind and cloud movements are difficult to forecast accurately over both short and long forecasting periods. Thus, the actual output produced by wind or solar projects could differ substantially from the forecasted output. This makes pre-scheduled dispatching forecast more complex.
3. As more conventional generation is replaced by renewables, overall system flexibility has been reduced as flexibility has traditionally been managed by ramping up and down conventional generators. It is difficult to ramp renewable generators given they are weather-dependent.

All of the above reasons make it more difficult for AEMO to pre-empt upcoming conditions and system configurations. More importantly, it is becoming increasingly challenging for AEMO to accurately forecast reserves and declare shortfalls precisely.

WHAT ARE WE DOING ABOUT IT?

AEMO has identified many action points for both short-term and long-term measures to deal with this problem. Most of them evolve around developing better capabilities and systems to improve AEMO's forecasting capabilities. We note however it has implemented some interim measures to deal with the immediate challenges. Of those we note two measures in particular:

i. **Semi-scheduled (i.e. renewable projects) plant being required to continually inform AEMO of any restrictions on their available capacity due to physical factors, ambient weather conditions and their market intentions.**

ii. **Semi-scheduled generators be obliged to follow their dispatch targets, in a similar manner to scheduled generators.**[3]

Currently, renewable generators are not required to strictly follow their dispatch target due to the variability of their input (wind and sun). There is no penalty if they deviate from a dispatch target.

As the renewable penetration continues to increase, it is becoming increasingly challenging for AEMO to manage the supply as more renewable generators deviate from their dispatch targets; some deviations being very significant. Consequently, AER is proposing these two rule changes to ensure renewable generators strictly follow their dispatch targets. This has raised many concerns amongst the renewable community regarding potential economic losses, including:

1. Substantial loss of generation revenue due to the need for each generator to meet a dispatch target based on a forecast, and therefore curtailing energy generation.[4]
2. A large increase in the trading requirements and obligations for renewable generators with a need for continuous real-time trading and serious investment in forecasting, trading and storage systems.[4]
3. Severely restricted operating flexibility of plants which significantly diminishes the financial viability of assets in comparison to the market rules at the time of the investment decision,[4] and
4. Unnecessary disincentives for investors which leads to reduced economic investment in renewable generation.[4]

3 http://www.coagenergycouncil.gov.au/interim-security-measures
4 https://reneweconomy.com.au/new-rules-would-hit-wind-and-solar-farms-hard-but-issue-could-be-solved-in-5-minutes-29184/

CHALLENGE 3
INCREASING DECENTRALISATION OF ENERGY SOURCES

Australia has experienced strong growth in Distributed Energy Resources (DER), such as Distributed Photovoltaics (DPV, or roof-top solar) over the past decade. South Australia and other parts of the NEM now have the highest DPV penetration in the world. Today, aggregate roof-top PV generation already exceeds the largest single scheduled generator in the NEM. The latest Integrated System Plan (2020) expects DER generation capacity to double or even triple by 2040; driven by residential, industrial, and commercial consumers continuing to invest heavily in DPV and battery storage. This energy source could provide 13% to 22% of total underlying annual NEM energy consumption by 2040.[5]

Most DPVs and other DERs (e.g. battery) operating in the NEM are not visible to nor manageable by AEMO, thus, are not subject to the same performance requirements as large-scale generation sources. As the penetration of DER continues to grow, these passive fleets have a growing aggregated impact on network voltage stability, challenging the way the Distributed Network Service Provider (DNSP) operates. South Australia and Queensland experience the most significant challenges owing to their high DPV penetration, exacerbated by these areas also having generally lower network capacity and higher impedance.

In addition, aggregate solar PV tends to reduce day-to-day operational demand load, particularly in the middle of the day when demand is low and solar PV exports are high at the sun's peak; commonly referred to as the 'duck curve' (see Figure 5). The consequence is a heightened risk of underestimating the impacts of DER from the midday trough through to the evening peak[6], which makes it difficult for AEMO to predict the system's load profile. Also, it creates a steep ramp period between midday and the evening peak as conventional generation is backed down during the day yet needs to ramp up rapidly in the late afternoon to meet peak demand. This could strain the operational capability of the system. Worse, being invisible to the operator, AEMO cannot curtail these generators even under emergency conditions.

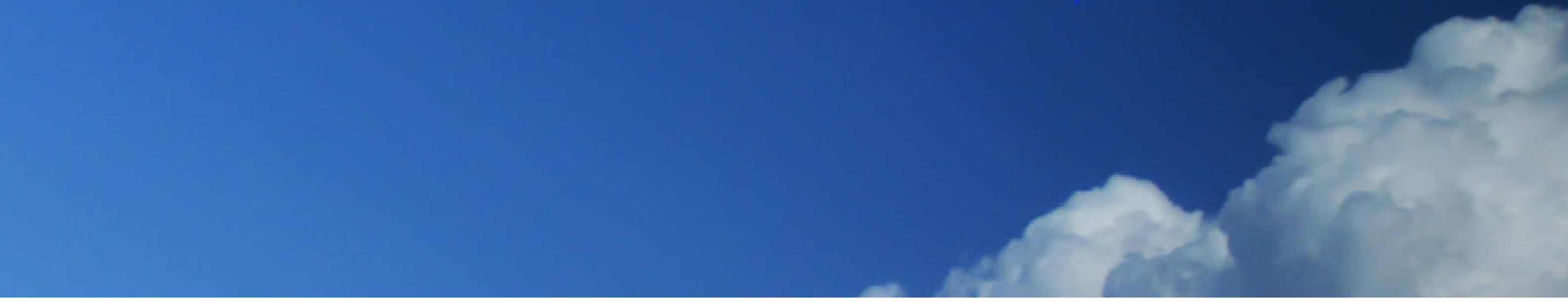
FIGURE 4: HISTORICAL (2019) AND PROJECTED (2025) MAXIMUM INSTANTANEOUS PENETRATION OF DPV

Maximum instantaneous DPV penetration (%)	Historical (2019)	Projected (2025, ISP Scenario)	
	Actual	Central	Step Change
South Australia	64	68	85
Victoria	31	45	66
Queensland	30	45	57
New South Wales	21	33	48
Tasmania	12	14	21

Source: AEMO 2020

5 AEMO, Integrated System Plan 2020

6 AEMC, Consultation paper – Technical standards for DER, 25 June 2020



WHAT ARE WE DOING ABOUT IT?

AEMO, AEMC (Australian Energy Market Commission) and ESB (Energy Security Board) are conducting three concurrent work streams aimed at improving the use and management of DER. The works undertaken are centred on three key parameters:

- Improve the technical requirements for DERs to better align their performance with both local distribution and bulk system operational needs. This allows DER to have better autonomous responses that support the system during normal operation and improve system resilience during large disturbances.
- Improve DERs' visibility and predictability so that the operator can make accurate forecasts for dispatch process and balance the supply demand during various peaks and troughs throughout the day.
- Introduce measures to actively manage DER so that the system operator is able to 'communicate' with these passive devices and potentially load shed in emergency scenarios.

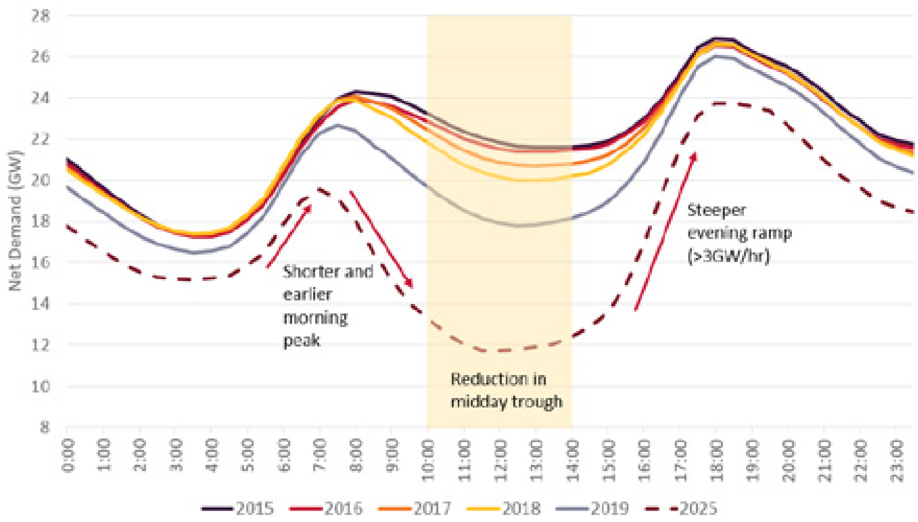
The regulators have already introduced several rule change requests centred around these parameters. The most notable ones being:

i. **Introducing a rule change to establish minimum technical standards for DER in the NEM.**

ii. **Developing new measures to improve compliance with both existing and new technical performance standards and connection requirements.**

iii. **Mandating minimum device level requirements to enable generation shedding capabilities for new DPV installations in South Australia (with other NEM regions and Western Australia encouraged).**

FIGURE 5: NEM 'DUCK CURVE' ANNUALISED



Source: AEMO 2020

iv. **Establishing regulatory arrangements on how DNSPs and aggregators could implement these plans as soon as possible.**

v. **Investigating the need to updating existing DPV fleets to comply with regional generation shedding requirements.**

By establishing DER technical standards, AEMO can expect a minimum level of predictable performance and behaviour by DER during constrained operations or system disturbances. Without establishing minimum technical standards, NEM system operations will become increasingly reliant on inefficient market intervention to manage waning system voltage, thermal capacity, or inertia. The risk of larger passive shut-downs; and, in quite rare instances system blackout events, will also be raised.

AEMC is currently undergoing public consultation on these new rule changes and is unlikely to reveal the final rules before 2021. Thus, it is too early to make a call on the implications for market participants.

However, we know in principle that Distribution Network Service Provider (DNSPs) will be obliged to include new DER minimum technical standards into the terms and conditions of connection agreements with their retail customers. It is anticipated this obligation will have the flow-on effect of binding manufactures and installers of DER devices to these minimum technical standards.[7]

The new rules will also require DNSPs to ensure compliance of connected DER with the standards on an ongoing basis. The devices required to comply could cover a wide range of households' electric devices such as solar PVs, batteries, air conditioners, electric storage hot water systems, pool pumps and electric vehicle supply equipment.

Based on the positive feedback from several DNSPs, we think the new rules are likely a positive development for DNSPs; as it may create new revenue streams from both regulated and unregulated avenues. We will follow up on this new rule in future analysis to gain a deeper understanding what this may mean for DNSPs, energy retailers and consumers.

7 AEMO, Rule change request – Minimum DER Technical Standards, 2020

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