Smart Meter Backstop Mechanism Capability Trial

February 2022

Phase 2 Evaluation Report

Important notice

Purpose

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Version control

Version	Release date	Changes
1	09/03/2022	Initial report

Executive summary

This report provides a technical overview of capabilities in South Australian smart meters that could increase consumer benefits and be utilised in maintaining power system security.

Context

Distributed energy resources (DER) continue to be installed at significant rates. Demonstrating how capabilities embedded within the 'behind-the-meter supply chain' can be harnessed to capture the full value of these resources will further support the energy transition in South Australia.

Phase 1 of this trial proved that residential smart meters have capability to actively manage distributed photovoltaic (DPV – rooftop solar) generation within the timeframes and reliability levels required to support power system security[1]. On completion of Phase 1 earlier this year, the South Australian Energy Minister formally approved AEMO continuing to trial capability latent in Advanced Metering Infrastructure (AMI) (or 'smart meters') in South Australia. With the capability proven under Phase 1, Phase 2 sought to specifically demonstrate how this functionality could be harnessed to enable new energy markets and enhanced information and choice for South Australian consumers.

The trial also sought to examine new ways to enhance the security of South Australia's world-leading transition by examining the in-practice benefits of aggregate near-real-time visibility of DER to operation of the power system, that was enabled under the government's 'Smarter Homes' program. As highlighted in the Energy Security Board's (ESB's) Post 2025 Market Design final report to energy ministers, improved DER data is required to optimise and support secure network operation and unlock benefits for consumers from their flexibility[2]. Aggregate DER visibility in near-real-time is essential to understanding when the power system is at risk, what measures need to be taken to mitigate these risks, and whether they have been successful, and to providing consumers with far better information to manage their bills.

Design and scope of the trial

This trial tested the *technical capabilities* of meters, which are the focus of this report. The market reforms required to further integrate DER into the power system are being progressed under the ESB's Post 2025 program.

Overview

Developing new energy markets requires minimum levels of functionality across the supply chain. The technology delivering the service must be proven, and the 'energy' response requires measurement and verification to enable market settlement. Under Commonwealth trade measurement laws, electricity meters used to facilitate trade must be pattern approved and verified so as to underpin trust in markets and deliver a service that is assured and can build trust and social license. As such, Phase 2 of this trial set out to demonstrate that DPV can utilise smart meters to deliver all these key elements and therefore enable a new market construct.

[1] Available at https://aemo.com.au/initiatives/major-programs/nem-distributed-energy-resources-der-program/standards-and-connections/reference-information.

[2] See https://esb-post2025-market-design.aemc.gov.au/32572/1629945809-post-2025-market-design-final-advice-to-energy-ministers-part-b.pdf, p 71.

To do so, Phase 2 performed testing of the physical disconnection of DPV at 17 commercial and industrial (C&I) sites through verbal communications from AEMO via distribution network service providers (DNSPs) to Metering Coordinators (MCs), and remote communication from MCs to the meter, with a total of over 1 megawatt (MW) under active management.

To test measurement and verification Phase 2 examined data from 270 residential consumer sites under 'Smarter Homes' metering arrangements, trialling the capability for MCs to provide near-real-time aggregate visibility of both gross and net load and DPV generation. Phase 2 incorporated the C&I sector because these systems generally have more complex CT metering arrangements, which differ to standard whole-current residential installations tested under Phase 1. Finally, the trial reviewed the outcome of some Relevant Agents using smart meters as the solution to provide their customers the remote operation of DPV as per the 'Smarter Homes' requirements.

Phase 2 was designed to build on the learnings from Phase 1 and gain a complete understanding of smart meters' end-to-end communication performance – robustness of response, measurement, trust, and near-real-time aggregate visibility capabilities.

The overarching outcome was to demonstrate that, under 'Smarter Homes' requirements, smart meters contain capability to provide South Australian consumers access to new markets and further benefit from the energy transition, while leveraging existing investment in the Australian Energy Market Commission's (AEMC's) *Power of Choice* framework.

The phases also successfully tested a complete set of functionalities required for smart meters to act as a last resort DPV cyber security safety switch.

Overarching outcomes

Consumer benefits – specific load and generation behaviour information

The trial proved that the near-real-time exchange of gross DPV and load data – that is, separated generation and load data feeds and not their combined performance – for the measurement and provision of information to consumers is feasible at low cost. Such specific and independent information enhances understanding of energy behaviour patterns and, in turn, consumer choice and control.

Typically, consumer billing information contains only the net behaviour of household devices, and consumers are unable to see the individual benefit of DPV against their household load, and in turn the true benefit or bill impact of load shifting behaviours. By 'separating' DPV and load data, this information becomes more accessible and could be made available to the consumer in near-real time. The consumer choices enabled by disaggregated real-time device level data at the premise has been found to reduce energy bills by up to 12%, or 35% when combined with smart energy saving programs such as real-time messaging, suggesting voluntary behavioural response[3].

Market demonstration and performance benefits

Phase 2 conducted a successful physical performance test of smart meters' remote capabilities for DPV management for C&I consumers, opening opportunities for these consumers to engage in emerging DER markets using capabilities already present at the premise. In doing so, the trial created a better understanding for all participants of the capabilities, speed and response of smart meters in South Australia. The smart meters

[3] See https://static1.squarespace.com/static/52d5c817e4b062861277ea97/t/56b2ba9e356fb0b4c8559b7d/1454553838241/Got+Data+-+value+of+energy+data+access+to+consumers.pdf and https://www.aceee.org/sites/default/files/publications/researchreports/e105.pdf.

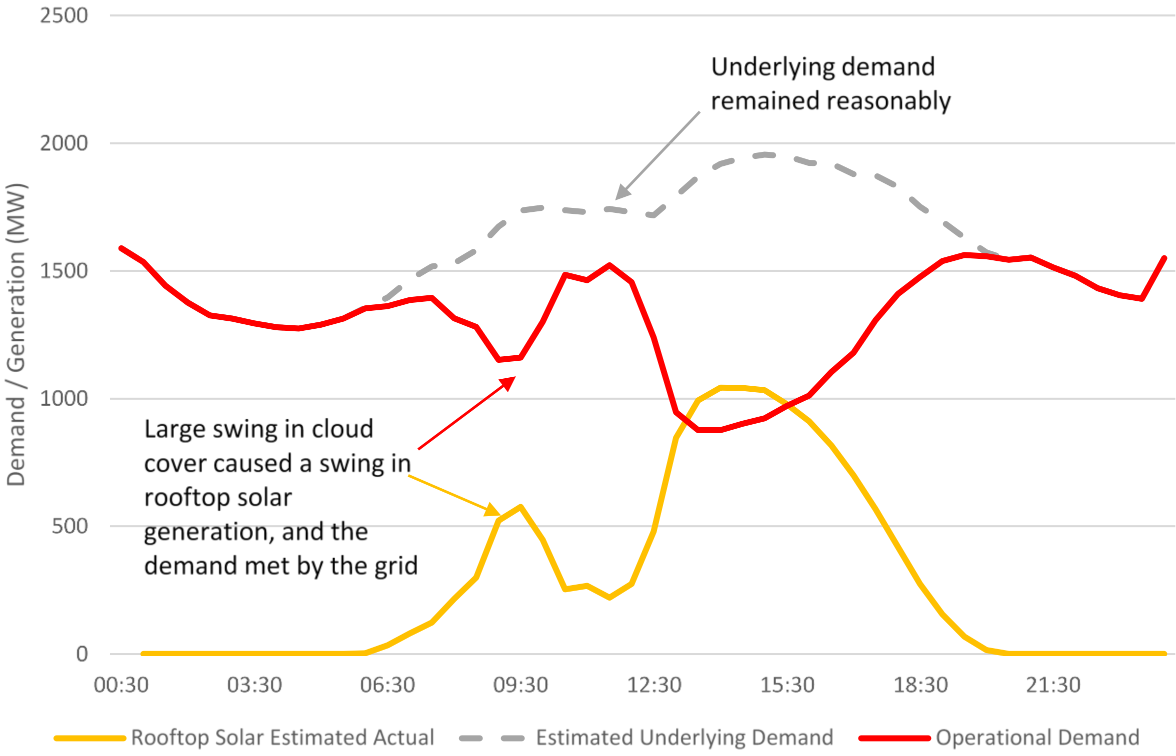
delivered response rates, accuracy and robustness at the levels required for market and power system operations, as detailed in this report. The trial proved simplicity of the solution using standardised widely available DPV systems.

Power system security benefits

This trial is part of ongoing and extensive AEMO forecasting uplift projects to manage emerging real-time operating risks and better integrate variable energy resources. The data obtained by the aggregate visibility piece of the trial demonstrated that in real time, an average of 96% of all metering data values from patent approved and verified meters were received before the start of the next interval. This speed, statistical relevance, accuracy and reliability is important for real-time operations to account for cloud formations over geographically small metropolitan areas, and the high variability and uncertainty of DPV generation these natural changes create.

Figure 1 illustrates this risk of fluctuating DPV ramp in South Australia during January 2021, when a cloud band resulted in a temporary drop in DPV generation. To maintain the supply-demand balance, the drop in DPV supply needs to be offset by an increase in other generation, requiring AEMO to take action via the market to dispatch scheduled and semi-scheduled generation. The chart shows that underlying consumer demand remained relatively stable during this time, however the flex required by the National Electricity Market (NEM)-sourced generation was significant. Events such as this highlight why AEMO needs to understand the total capacity of DPV assets and their aggregate behaviour in near-real time, so the system can be configured to respond to the expected change to keep the system in balance while also producing the best transparent market signals which the market can act on. The fluctuations demonstrate that without understanding of the whole operational envelope – including DER, associated uncertainty and likely behaviour – management of power system security may be compromised.

Figure 1 South **Australian** demand and DPV generation, 13 January 2021



AEMO already uses 5-minute data sets within its existing forecasting capabilities;, however, without improved accuracy and understanding of variability in forecasting aggregate DPV behaviour as penetration increases, AEMO considers it will not be able to manage these fluctuations and configure the power system in a way that maintains security and ensures the most efficient outcomes for consumers. The trial sought to demonstrate that short latency, verified and accurate DPV data across the fleet is required to improve intra-day and nowcasting techniques, enhancing operational situational awareness for management of high DPV penetration for power system security purposes in real time.

To do so, the trial sought to more clearly identify and better forecast the real-time variabilities of DPV generation in 5-minute intervals. The trial used DPV generation data feeds from a broader number of selected systems with precision certified measurement capability, both of which enhance statistical accuracy which was expected to assist forecast capability.

In managing intra-day DPV fluctuations, differences in some intervals between the trial's forecast DPV generation and DPV forecasting estimates utilising smaller data sets were in the order of 200 MW. This highlights that the fluctuations of DPV can be more reliably detected with more granular, selective and trusted data.

This accuracy and reliability are critical in enabling the situational awareness required for real-time management of a high DER power system, as further demonstrated in Figure 2.

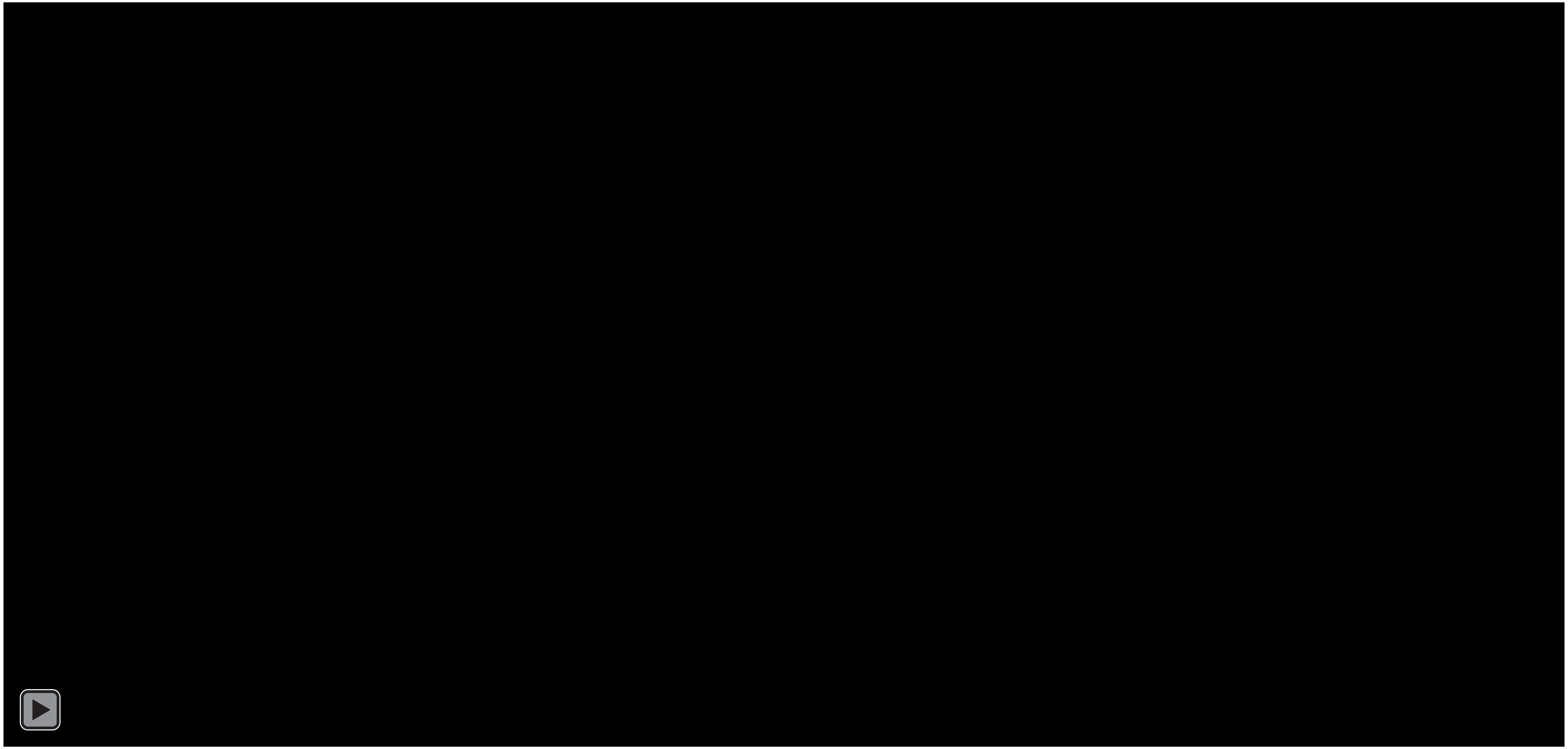
Figure 2 shows the significant increase in instantaneous DPV generation in South Australia over the past decade, in 30-minute intervals plotted with the scale of the generation swing that occurred. DPV is represented by the orange 'dots', with larger 'dots' representing an increasing dominance of the total 30-minute generation capacity, up to 2,500 megawatt hours (MWh). The generation swing is shown by the simultaneous joint placement of two plotted 'dots' on either side of the Y axis '0' that represents the ramping neutral point (and by pressing the 'play' button). The plotting shows 30-minute DPV ramps are becoming wider (currently up to around 700 MW[4]) and more frequent, while also accounting for a larger portion of instantaneous total generation capacity.

As the historical change over the past decade demonstrates, these fluctuations will continue to magnify as DPV penetration increases, necessitating enhanced forecasting capability to operationally manage them in real time. The control room must be able to accurately understand, prepare for and respond to the ever-increasing scale, frequency and geographic impact of cloud cover suddenly reducing unprecedented amounts of DPV generation.

The trial data demonstrated capability exists in every consumer premise with DPV to improve real-time understanding of these fluctuations, and the importance of the South Australian Government's 'Smarter Homes' requirements to activate this metering capability for every new DPV system installed. The improved forecast was generated from revenue grade metering which is considered a ubiquitous device designed and constructed as a cost-effective, precision certified measuring instrument enabling market settlement for existing and potential future services. These meters and their supporting communications infrastructure including the associated data processing were proven to be secure and robust. Leveraging this existing capability made possible by 'Smarter Homes' and extensive investment in the *Power of Choice* reforms, delivered successful outcomes for this trial, supplying energy data to the market, while not impacting the delivery of consumers' requirements.

[4] The swings are calculated by adding the total change from the negative through to the positive.

Figure 2 30-minute variable renewable energy (VRE) ramps vs 30-minute renewable energy (RE) average penetration: 2008, 2018 and 2021



Above is a ‘playable’ (i.e moving) chart showing the extreme scale of change in DPV ramping over the past decade, and in turn the requirement for enhanced aggregated visibility of DER. To enable full functionality of the chart, please download a copy of the report to desktop and enable all features in Adobe Acrobat Reader.

It is critical that AEMO continues to uplift visibility of variable behind-the-meter assets, to enable estimation of the entire operational envelope for which power system security must be maintained. Initiatives such as a nowcasting trial in South Australia are underway to investigate potential improvements in the near-term (approximately 0 to 4 hour-ahead forecasts)[5]. Of equal importance to improving forecast accuracy is improvements to the forecast risk and uncertainty of DPV generation.

Summary of detailed key learnings from the trial

The following capability is delivered via the addition of a simple twisted-pair wire between CT metering and the inverter, and as a minimum mandatory requirement under South Australia's 'Smarter Homes' program. Under this program new DPV installations must be isolated at the meter via two element metering. The Office of the Technical Regulator's deemed to comply wiring diagrams detail how these installations are to occur and exemptions that apply[6]:

- Smart meters can actively manage and measure DPV generation in a manner that provides the consistency and certainty in measurement required under trade measurement laws to support fair and open competition. This can offer access to new markets for South Australian consumers.
- Smart meters can actively manage DPV to support power system security at the necessary levels of speed and reliability.
- Aggregate gross visibility of DER can be achieved via smart meters, with minor improvements to data exchange platforms that were easily constructed under the trial. This 5-minute aggregate data enables 'visibility' that provides:
   i. Consumer information: enhanced data in a consistent form, quality, accuracy and timeliness. Leveraging existing digitised infrastructure is an implementation of a modernised consumer centric energy supply chain. The functionality provides clear and simple information that could be accessed in near-real time enabling consumers to make better choices delivering greater agency and control over their energy use and devices.
   ii. Situational awareness: an increase in data sets improves accuracy in reconstitution of the supply/demand balance in a high DER system, providing an accurate understanding as to whether the power system is expected to remain in a secure state or further action is required.
   iii. Significant forecasting accuracy improvements: the trial highlighted that visibility is improved with additional near-real-time aggregate data with some forecast scenarios having indicated a variation in the order of 200 MW for a dispatch interval. Such visibility of these variations will be critical in managing real-time contingency events.
- This aggregate 5-minute DPV data from Smart Meters can be provided to AEMO without additional devices, communication modules or reliance on consumer internet access.
- The trial demonstrated that consumers were willing to participate in new market arrangements to support the power system.

[5] For further information on the ARENA funded SA Nowcasting trial, see https://arena.gov.au/projects/gridded-renewables-nowcasting-demonstration-over-south-australia/.

[6] While this is one means to deliver this functionality, AEMO supports a principles-based approach to technology and meters delivering this capability via other innovative means if possible.

- The C&I sector represents a considerable growth sector for new DPV systems of considerable size. This demonstrates an opportunity to embed minimal cost functionality that can offer consumers the ability to increase their savings while also supporting the power system.
- The response worked with export limiting controls enabled on the inverters.
- This trial was delivered with existing systems and processes and if it was to move to a business-as-usual activity then additional development and cost may be required, however this would also improve the speed and robustness of the solution.
- There is approximately 5.3 MW of DPV installed at 107 sites in buildings operated by the South Australian Department of Education which could be considered for retrofitting.
- Further, the close collaboration that occurred with Metering Coordinators and Metering Providers in delivering this trial identified other additional advanced, low-cost metering capability that could be harnessed to support mitigation of emerging power system security risks related to high DPV penetration. The capabilities that smart meters configured in this manner could deliver include:

  i. Under-frequency load shedding (UFLS): this last resort power system security tool is being gradually eroded due to net exporting feeders. Further testing is required but discussions indicate meters can be programmed to appropriately and automatically respond to an UFLS event.
     - Such capability would mitigate the risk of impacting life support customers inherent within traditional shedding at the feeder level, by allowing a targeted response to UFLS events

  ii. Over-frequency generation shedding (OFGS): the gradual erosion of OFGS capability with forecasts showing DPV generation in South Australia is a growing coordination issue.

  iii. System Restart Ancillary Service (SRAS): this capability pertains to re-starting the power system following a system event after a large-scale blackout of the entire power system. System restart requires a minimum and stable level of load, both of which are reducing with increasing levels DPV installed. Smart meters offer near-instant management of DPV to deliver a stable load, while direct to inverter-based models of DPV control generally utilise consumer Wi-Fi, which appear to have a re-connection lag that may impact the utility of the inverter communications pathway to support system re-start.

  iv. Cyber Security Safety Switch: as with any internet-connected home appliance, the cloud infrastructure connected to DPV is vulnerable to incursion. DPV in aggregate is now the largest generator in the NEM, and illicit control of a portion of this fleet would risk power system security. Were DPV systems breached by a sophisticated actor, regaining immediate or short-term control of the compromised DPV fleet, and in turn the broader power system, could be challenging. Smart meters offer redundancy to this risk via capability to disconnect DPV through a secure and independent switch. The NEM's Power System Data Communication Standard[7] applicable to controlling generating plant and network infrastructure requires backup communications pathways. In regards to the control infrastructure operating DPV, no such redundancy currently exists.

Application considerations

This report focuses on the technical capabilities of advanced meters and their associated infrastructure, particularly in the NEM where significant investment has occurred in this sector under the AEMC's *Power of*

[7] Available at: https://aemo.com.au/-/media/files/electricity/nem/network_connections/transmission-and-distribution/aemo-standard-for-power-system-data-communications.pdf?la=en&hash=9D6BCA32B459E2CF98A67CF89E43CC63.

Choice framework. It shows even further that the capabilities for generation, distribution, storage, and operational management of energy is occurring via a ‘behind-the-meter supply chain’. The design of this new supply chain must occur efficiently. In seeking the most efficient means to operate the ‘traditional’ power system and local network operations, minimum capabilities are sourced from across the traditional supply chain. For example, a large generating unit may provide a level of reactive power support while a transmission line can also provide for fault-current / system strength.

In this regard, different areas of the behind-the-meter supply chain are likely also required to deliver different types or levels of operational and consumer functionality, and redundancy. Not everything should be sourced from one technology as different technologies deliver different capabilities and efficiencies. In some areas the functionality as outlined a smart meter can deliver could also be provided from an inverter, home energy management system or from a storage device, enabling efficiencies as occurs with voltage management within the ‘traditional’ network. This report seeks to highlight the potential for metering in this mix, in order to support the most efficient means of DER integration via the role smart meters could play in delivering consumer and system capabilities, and levels of redundancy – another key feature in traditional power system design and operation.

Different jurisdictions may need to consider their different regulatory arrangements to enable appropriate parties to access the functionality advanced metering can provide, such as the enhancements in aggregate visibility and situational awareness outlined in this report. New mechanisms and frameworks may need to be established to enable the ‘behind-the-meter supply chain’ to operate efficiently and ensure the *minimum* capability to operate the power system currently provided by traditional means, and able to be accessed by required parties, remains available and accessible to these parties to realise these benefits, especially by consumers.

Potential next steps

- Trial to test the ability for this technology to assist in UFLS, OFGS, SRAS and the demand response of appliances within the smart meters’ measurement and control.
- Examine what markets can be enhanced utilising this “new” capability by exploring barriers to current market offerings from providing pool-price exposure.

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1 Trial Phase 2 overview

1.1 Trial objectives

The Energy Security Board's (ESB's) Post-2025 Market Design identified that "*The protection of customers in an evolving marketplace requires new approaches … data and technology are essential enablers to make this happen, but work is needed to make sure standards are in place to support effective sharing and communication of data, and market systems need to be fit for purpose to meet the needs of the future NEM*[8]." This Smart Meter Capability trial ('trial') set out to identify efficient means for consumers to access timely and more useful data alongside the platforms required for the information provision to occur. To do so, the trial focused on leveraging existing infrastructure commonly available to every home and business under the *Power of Choice* reforms and the significant investment in data exchange platforms that has already occurred under this project but is currently underutilised.

Further, Minimum System Load (MSL) and the unintended disconnection of distributed photovoltaic (DPV) systems during system disturbances represent increasing risks to power system security in South Australia, and are emerging as risks quickly in other jurisdictions[9]. This trial sought to test newly developed operational capability as another tool to contribute to the management of these risks, and to demonstrate application of this capability for market and consumer benefits.

Phase 1 targeted the development and testing of metering capability and protocols to enable the emergency management of consumer premises with DPV to support power system security. All tests were simulated with a key objective of the trial being zero impact on consumers. The Phase 1 report can found on AEMO's website[10].

Phase 2 of the trial, the subject of this report, had a number of parts:

- The trial is investigating the capability for commercial sites' DPV to be curtailed using existing standards and devices which are configured in a way to provide this remote operation. Phase 2 trialled the actual disconnection of DPV through verbal communications from AEMO via distribution network service providers (DNSPs) to Metering Coordinators (MCs) and from MCs to the meter via remote communication capability. Outcomes from this phase provided insights into how control capability within commercial and industrial (C&I) sites can offset potential power system security risks, and what incentives may potentially be utilised for C&I sites to engage in markets utilising this functionality.
- Phase 2 also leveraged the South Australian Government's 'Smarter Homes' arrangements and the capability for MCs to provide near real-time visibility of gross and net load and DPV energy at a consumer site. This aggregate near-real-time visibility was delivered to AEMO via an industry standard application programming interface (API), and Phase 2 assessed this delivery mechanism, its accuracy, and the benefits of additional 5-minute data to that which AEMO already utilises in forecasting, in supporting operation of a high distributed energy resources (DER) power system.

[8] Available at https://esb-post2025-market-design.aemc.gov.au/32572/1629945809-post-2025-market-design-final-advice-to-energy-ministers-part-b.pdf, p. 64.

[9] For more information see https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/power_system_ops/consumer-fact-sheet.pdf?la=en.

[10] Available at https://aemo.com.au/initiatives/major-programs/nem-distributed-energy-resources-der-program/standards-and-connections/reference-information.

- Finally, Phase 2 of the trial reviewed the outcome of some Relevant Agents that were using smart meters to provide their customers the remote operation of DPV as per the 'Smarter Homes' requirements. On 14 March 2021, AEMO instructed NSPs to maintain minimum operational demand in South Australia. In response to this instruction, SA Power Networks called on DPV management capability to be enacted, and this report reviews the response of smart meters in this real-world operation.

The overarching aim was to leverage the learnings from Phase 1 and set out to build a complete understanding of smart meters' end-to-end communication performance, covering the robustness of response, measurement, trust, and near-real-time aggregate visibility capabilities. The objective was to demonstrate that under 'Smarter Homes' requirements South Australian smart meters contain the capability to provide South Australian consumers with better information on their energy use and access to new markets, while leveraging existing investment in the Australian Energy Market Commission's (AEMC's) *Power of Choice* framework to also support power system security. Table 1 displays a breakdown of the objectives and results for the Phase 2 trial.

Table 1 Summary of objectives of trial

Objective	Was this achieved?	Commentary
Extension of the operational protocols developed in phase 1 to remotely curtail and restore selected Commercial and Industrial consumer sites (AEMO – TNSP – DNSP – Metering Coordinator)	Yes	• This phase of the trial utilised the SA Power Networks Relevant Agent framework for communication.
Provide enhanced near real-time visibility and analysis of the dataset	Yes	• 5-minute energy data from selected smart meters was retrieved using standardised APIs and this data was analysed and used to improve upscaled estimates of DPV generation.
Provide greater understanding of the capabilities and time of response from Metering Coordinators to consumers' smart meters	Yes	• Speed of response data was provided in time to improve power system operation in real-time
Demonstrate the benefits of this capability to consumers and the market	Yes	• The trial provided gross DPV generation data in real-time11 . This data would enable consumers to see the real output of their system against their load, enabling choice via a new awareness of the impact of consumption against DPV generation. • Success of the capability demonstrates opportunities for the development of voluntary load markets (for example, pool pump or DPV curtailment) and hedging opportunities.
Determine whether existing standards and devices be configured at a consumer site to provide this remote operation control of DPV	Yes	• Can be done with minor changes on site (e.g. a twisted pair wire connected from the meter to the inverter/s) • Multiple inverters can be connected to one smart meter
Review of the actual event on the 14th March 2021	Yes	• Reviewed the actually physical response of Smart Meters as part of the Relevant Agent framework

TNSP: transmission network service provider; DNSP: distribution network service provider.

1.1.1 Trial description

Phase 2 of the trial focused on collaboration with trial participants to jointly extend the protocol and capabilities that were developed in Phase 1. This extension included a focus on C&I sites and examining the benefits of aggregate near-real-time visibility of DPV.

[11] Only aggregate data sets were sent to AEMO.

The protocols and capabilities from Phase 1 provided an avenue for the power system operator to give instructions to NSPs, to pass on to MCs, to remotely curtail and restore selected residential consumer sites via the smart meter. Phase 2 extended this capability to include C&I sites via an alternative metering arrangement which permitted the DPV inverter to be interfaced with the smart meter.

The trial is also a component of a broader suite of AEMO forecasting uplift projects to integrate DER and manage their variability of output in near-real time. Leveraging 'Smarter Homes' requirements for a two-element meter and small wiring change in South Australia, the trial was designed to explore whether – and demonstrated that – these minor changes[12] resulted in these meters being capable of providing a richer dataset that improves power system forecasting scenarios, and in turn control room situational awareness.

Phase 2 was a technology trial which was undertaken to understand any shortcomings of smart meter capability to interface with DPV and exchange gross data in real time. This technology trial was not looking for a vendor solution, but rather to test the capabilities across many DPV inverters and MCs for this technology to provide consumer benefits and support power system security during rare conditions.

This phase of the trial used established communication channels and protocols from AEMO to NSPs to MCs, for the curtailment of only DPV at C&I consumer sites via smart meters. Scripted phone calls were used between the participants, with the MC sending a signal to the meter to test the disconnect and reconnect functionality. This signal did not impact consumer load connections.

The trial did not involve:

- Physical disconnection of load at consumer sites. The trial isolated generation from load by installing capability for the smart meter to interface directly with the DPV, allowing curtailment/restoration of only the DPV (consumer load was unaffected).
- Testing only one vendor; rather it was a technology trial which included many DPV inverters and MCs.
- Any regulatory framework changes (this trial was a Proof of Concept conducted within the existing regulatory environment).

1.2 Trial participants

Phase 2 trial participants and their roles are listed in Table 2.

[12] AEMO supports a principles-based approach to delivering technology, capability, and minimum functionality. In this scenario the minor additional wiring is one known and now understood approach to delivering this aggregate gross near-real data via the meter, but this does not preclude metering vendors enabling the provision of this information by other technical options.

Table 2 Trial participants and roles

Name	Role
AEMO	• Developing and coordinating the trial. • Analysis of the data
TNSP – ElectraNet	• Participate and collaborate in the development of the operational protocols in workshops.
DNSP – SA Power Networks	• Participate and collaborate in the development of the operational protocols in workshops. • Follow and execute the developed protocol.
Metering Coordinators – • **PlusES** • **Metropolis** • **Yurika Metering**	• Participate and collaborate in the development of the operational protocols in workshops. • Execute the developed protocol and provide AEMO with datasets following the test. • Configure the sites to provide the capabilities to shed and restore DPV only
Metering Provider – EDMI	• EDMI supplied the standardised interface for AEMO to read Meters from pre-selected Plus ES smart meters.

1.3 Consumer and stakeholder engagement, and benefits

Phase 2 of the trial consisted of engagement with the voluntary participants including AEMO (trial lead), ElectraNet, SA Power Networks, MCs, and Metering Providers. It was identified that residential consumer and other stakeholders would not be impacted by the aggregate near-real-time visibility aspect of the trial, so no direct engagement was required during this phase.

As the intent of the trial was to actively manage C&I DPV, voluntary participation of these consumers was required. It was agreed with all participants that due to MCs having a direct relationship with C&I consumers, it would be their role to engage with them. Due to the type of C&I consumers, some MCs opted to reward them for participation with an arrangement to compensate, which correlated with the amount of DPV disconnected.

The trial was able to provide valuable market insights into the potential benefits and value of utilising existing installed smart meters as an interface to the curtailing and restoring of DPV only – independent of the consumers' load. The extent to which the trial outcomes contributed to better understanding or realising of this potential is outlined in Table 3.

The outcomes of this trial provide an opportunity to broaden industry understanding of the latent capabilities in smart meters that have potential to support power system security and unlock additional value for all consumers.

AEMO considers that the broader implementation of mechanisms and markets delivering consumer and power system security services will require broad engagement and understanding of the impacts and benefits to consumers and industry.

Table 3 Potential benefit and value of trial outcomes

Potential benefit/value	Impact/commentary
DER visibility improvements	• The trial provided gross DPV generation, gross load consumption, and the net of these two sets in near-real-time*. This data, available via already installed smart meters, could now be provided to consumers to better understand the impact of their energy use patterns and enable innovations in interactive energy services for consumers. • Success of the capability trial demonstrates opportunities for the development of voluntary load markets (for example, pool pump or DPV curtailment) and hedging opportunities. • The remotely read smart meters (type 4 meters under NER chapter 7) provided a statistically valid sample of the population. These meters provided load profiles at 5- and/or 30-minute intervals. • More 5-minute data feeds of actual DPV (gross) generation in aggregate enhanced validation of existing forecasting tools. • Likely a more efficient solution utilising existing equipment and PoC communications infrastructure • Enhanced real-time operational situation awareness of changes in the system due to load and generation.
Managing DPV generation of this nature could present a viable option as a DER market	• The capability functioned successfully and within timeframes required for market and operational responses.
Reduction in the number of consumers that might be impacted during interventions for power system security via resource targeting	• This phase of the trial highlighted an efficient way for networks to manage load to support power system security objectives during emergencies – using a target rather than blanket shedding approach.
Approach could be effective for other jurisdictions	• It is concluded that the protocols and capabilities would work in other jurisdictions. However further consideration in Victoria would be required to understand any differences in the implementation and capabilities of Victorian AMI smart meters compared to *Power of Choice* meters in the rest of the National Electricity Market (NEM, as used in this trial). This trial required the configuration of standardised DPV inverter (AS/NZS 4777.2 and *Power of Choice* meters) which are both existing deployed technology.
Understanding of the requirements and mechanisms required for the current capabilities to participate in RERT, LOR or for market purposes	• Communication and response were key outcomes of this trial. Current systems and processes were found to be suitable within the trial. However, if BAU arrangements were to be established, the systems and processes could need further development to enable automated DPV dispatch and more fit for purpose measurement and verification models.

RERT: Reliability and Emergency Reserve Trader; LOR: Lack of Reserve.
* Only aggregate data sets were sent to AEMO.

2 Protocol response time evaluation

2.1 Trial protocol map

Figure 3 shows a high-level interaction and process diagram for the operational protocol used in Phase 1 of the trial. As in Phase 1, for Phase 2 it was agreed that all systems' level communications were to be conducted via phone calls, with follow up emails for traceability.

Unlike Phase 1 where the protocol began with AEMO providing an instruction to ElectraNet to initiate the DPV curtailment, Phase 2 comprised AEMO providing this message directly to SA Power Networks, which then followed the 'Smarter Homes' protocol for Relevant Agents. SA Power Networks called MCs who in turn tested the communication to their metering fleet at selected sites voluntarily participating in the trial for the curtailment and restoration of DPV only.

Logs of the interactions were kept by all participants during the trial. Each interaction of the protocol was mapped for both the activation and the restoration (cancellation); see Figure 3 and Figure 4, respectively. The overall time for AEMO to receive confirmation the instruction had been activated at the device level was on average less than 10 minutes. This timing meets AEMO's requirements to manage the return of the power system to a secure state following a system event and for the capability to be used as a market for consumer benefits.

Figure 3 Timing of the chain of command for curtail operation

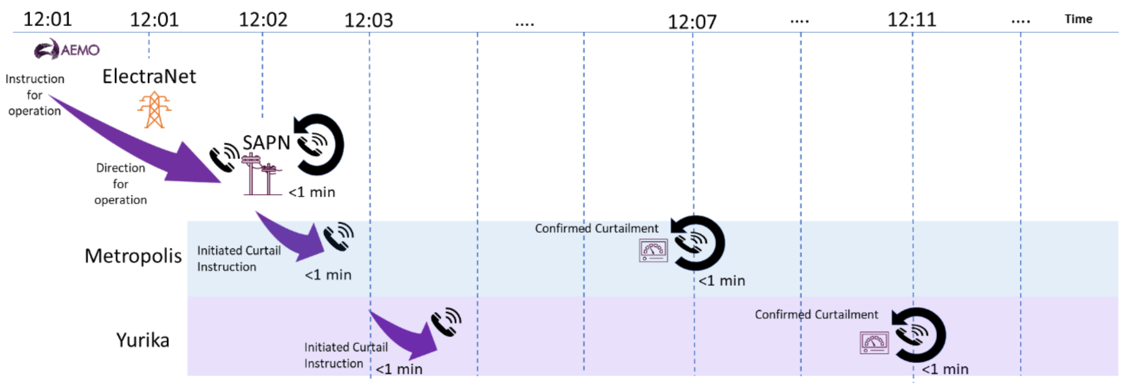
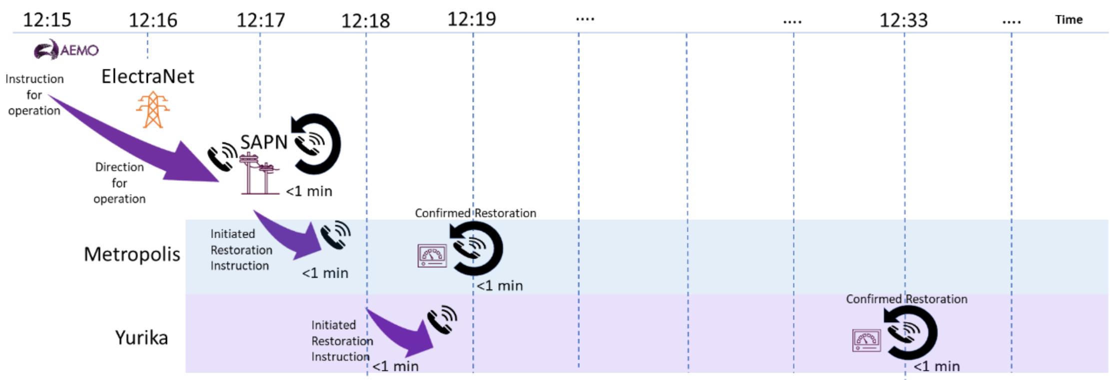


Figure 4 Timing of the chain of command for curtail restoration operation



3 Advanced Metering Infrastructure: framework evaluation

This section of the report will focus on the ability to implement the actual physical response measured for DPV curtailment, and the data which provides enhanced aggregate near-real time visibility of DPV.

3.1 Site selection, number and type

Each MC preselected a sample set from its metering fleet installed in South Australia. These smart meters were all remotely read meters as defined in chapter 7 of the National Electricity Rules.

A number of different commonly available PV inverter brands and models were interfaced to allow the smart meter to curtail and restore the inverters, as shown in Table 4.

Table 4 Number of site and details for each Metering Coordinator as sample fleet for trial

Site	DPV Inverters Size per site (kW)	System	Metering Coordinator	Postcode
A	20	SMA AUSTRALIA PTY LTD STP20000TL-30	Metropolis	5070
B	100	(ABB) POWER-ONE ITALY S.P.A PVS-100-TL		5550
C	100	Fronius (27.0-3-S x 4)		5550
D	100	(ABB) POWER-ONE ITALY S.P.A PVS-100-TL		5550
E	100	Fronius (27.0-3-S x 4)		5550
F	100	Fronius (27.0-3-S x 4)		5550
G	100	(ABB) POWER-ONE ITALY S.P.A PVS-100-TL		5550
H	100	(ABB) POWER-ONE ITALY S.P.A PVS-100-TL		5550
I	100	Fronius (27.0-3-S x 4)		5550
J	30	Fronius (x2)	Yurika	5007
K	5.4	Fronius		5034
L	8.02	Fronius		5109
M	8.93	Fronius		5113
N	5	Fronius		5211
O	20.0	SolarEdge		5159
P	35.3	SolarEdge		5048
Q	99.43	SolarEdge (x4)		5068
R	99.43	SolarEdge (x4)		5031
S	29.9	SolarEdge		5157
TOTAL	1,161.41	kW		

These sites were a mixture of large commercial, industrial, and government buildings such South Australian Education buildings (10 schools). These government sites were selected following a desktop analysis, and focused on criteria such as distance from Adelaide CBD, size of PV system, make and model of inverters, and current works on these sites. This review also indicated that there were a number of DPV sites which could be retrofitted with the smart meter solution, including a further 5.3 megawatts (MW) of DPV from 107 Department of Education sites with systems sized between 5 kilowatts (kW) and 100 kW. The load profiles of these sites are particularly of interest, as minimum system load events are forecast to occur, and have occurred, on weekends and public holidays during which these sites are running at reduced loads, and therefore DPV curtailment on these sites is thought to have reduced financial impacts.

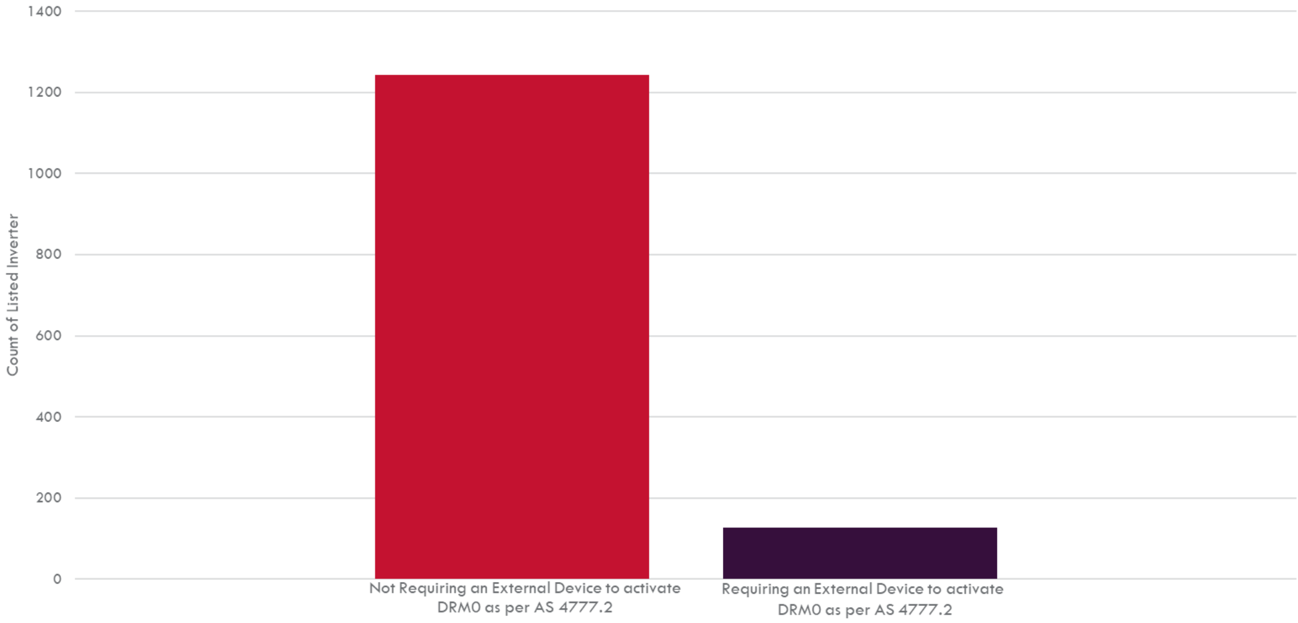
3.2 Harnessing *Power of Choice* and existing capabilities

All inverter energy systems connected to distribution networks of the National Electricity Market (NEM) and Western Australia's Wholesale Electricity Market (WEM) are required to comply with local DNSPs' connection standards, which include compliance to AS/NZS 4777.2. Since the 2015 revision of AS/NZS 4777.2, one of the minimum capabilities is Demand Response Mode 0 (DRM0). This allows inverters to be fitted with a Demand Response Enabling Device (DRED), which is analogous to a simple switch which turns a light on and off.

Existing smart meters have auxiliary outputs which can be used as these switches. They were originally provided for load control and interfacing to consumers' site Energy Management Systems as a method to read real-time energy consumption. These switches can be configured to be operated remotely or automatically based on site conditions or a timer.

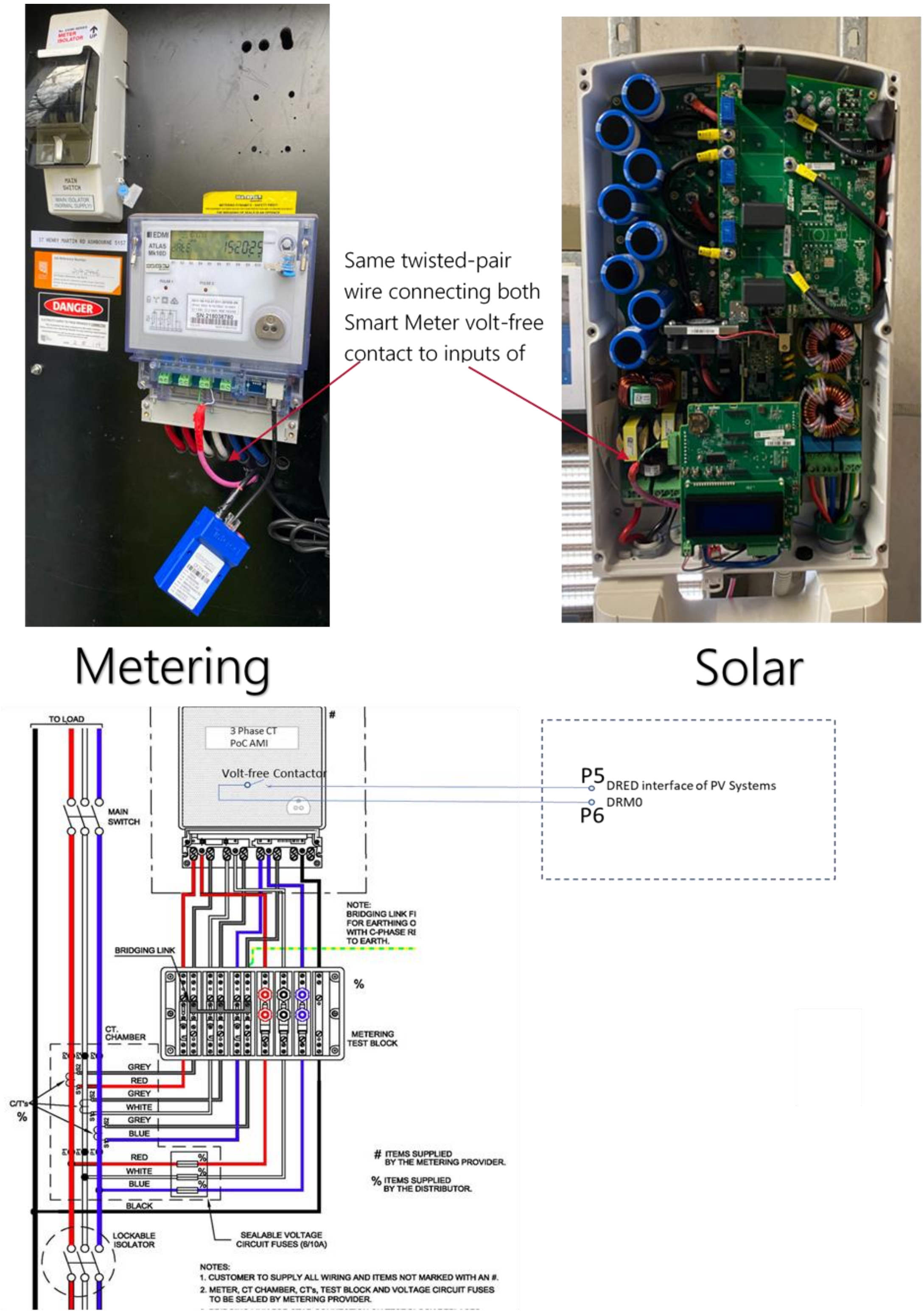
The trial looked to leverage both these standardised minimum levels of capability – the DRM0 and the auxiliary outputs of the smart meters. This involved the physical connection of a twisted-pair wire between the smart meter and the inverter. This approach for a minority of inverters required some additional interfacing hardware, as the standard requires only that inverters must be DRM0 'capable', and historically some inverter manufacturers opted to use additional hardware to provide DRM0. However, a review of the most recent Clean Energy Council (CEC) List of Approved Inverters demonstrates that the majority of inverters on this approved list do not require any additional external devices in addition to a DRED to activate DRM0, as shown in Figure 5. This demonstrates the ubiquitousness of this option to manage DPV using smart meters.

Figure 5 Count of current compliant inverters registered with Clean Energy Council Inverter Listing highlighting that most do not require additional external devices in addition to a DRED to activate DRM0



The hardware required in most cases in this trial was a single twisted-pair wire, connected to the volt-free contacts (basic switch) of the smart meter to the inverter. This did not require any protocols conversions, hand-shaking, provisioning or registration processes. Some inverters did require configurations to be selected to activate the DRED interface inputs. Figure 6 shows the wiring arrangement between the smart meter and inverter.

Figure 6 Hardware required to connect standard Smart Meter to AS 4777.2 DPV inverter



With this wiring in place, the capability to disconnect DPV only is then available to the MC and the consumers' existing retailer via the existing *Power of Choice* infrastructure, which has already entailed significant investment (alongside the consumer and system aggregate visibility benefits discussed in Sections 0 and 3.4.6). This includes existing communication channels and cyber security protections. This wiring option is one means to deliver this enhanced functionality. AEMO supports a principles-based approach to capability and technical development and would welcome innovation of means for the meter to deliver this functionality.

3.3 Actual physical response results for DPV curtailment

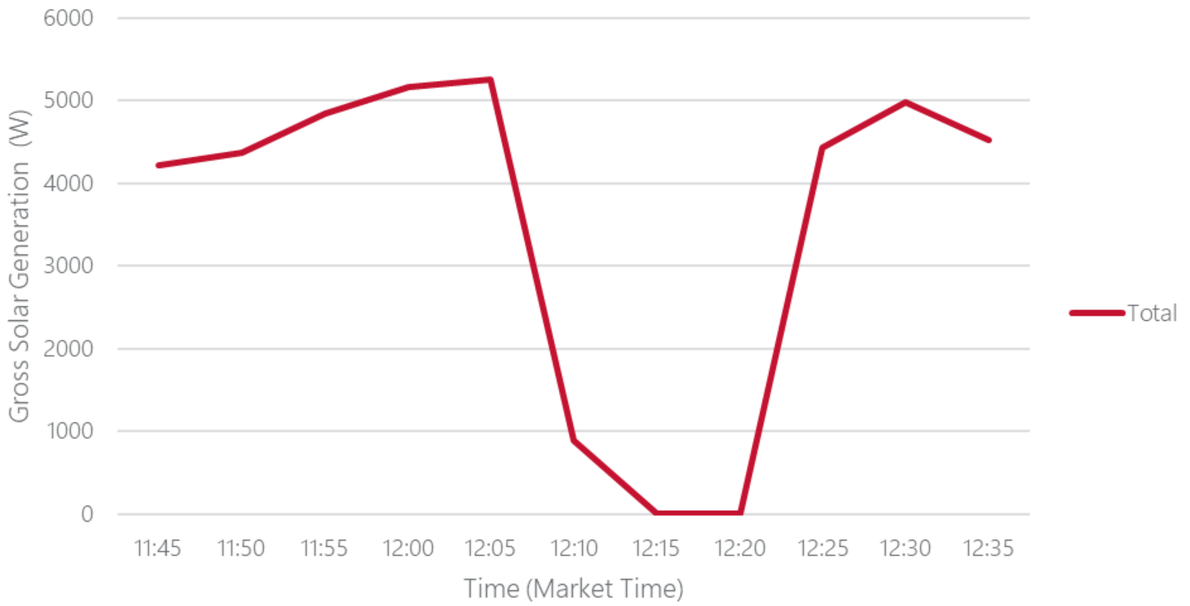
MCs were able to remotely activate DRM0 or DRM5[13] response modes as per AS/NZS 4777.2 following the connection of the smart meters and inverters. This remote signalling leverages the smart meters' existing cyber secure *Power of Choice* communications infrastructure and provided near-real-time data of the response. This response was the curtailment of DPV generation only, and the customers' load remained unaffected.

The tests were conducted to the times specified in Section 2.1. The below analysis was achieved by using 5-minute interval data from the smart meters which had individual monitoring of the DPV generation. This data was aggregated for all selected sites, and Figure 7 and Figure 8 below clearly highlights the curtailment of generation around 12:05.

Figure 7 Aggregated 5-minute interval gross DPV generation (no site loads)

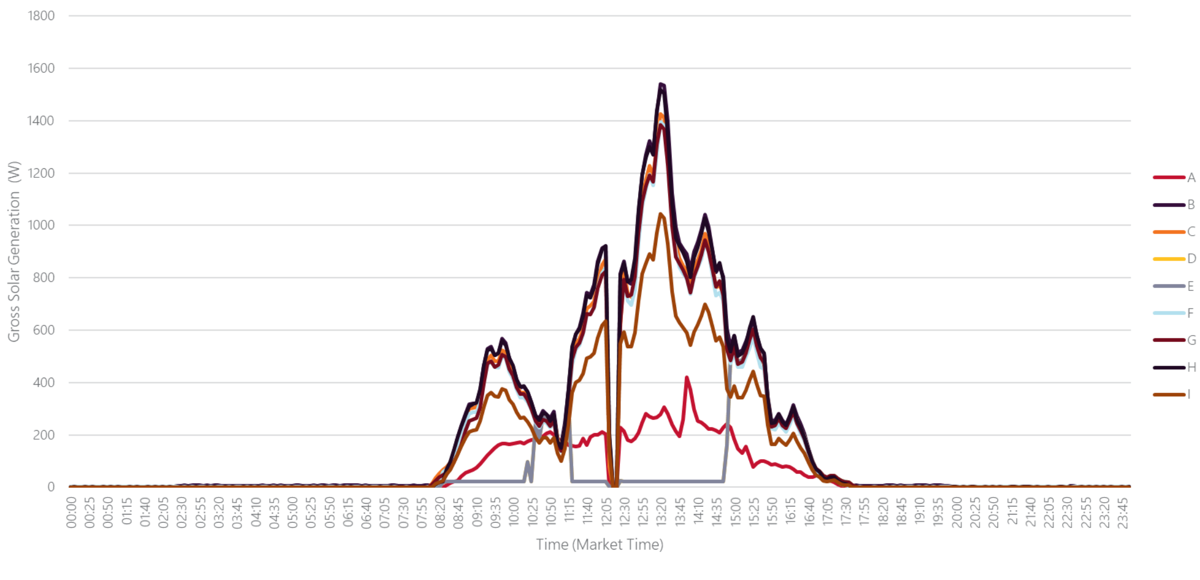
[13] DRM5 – no discharge of energy from the inverter

Figure 8 Aggregated 5-minute interval gross DPV generation, reduced scale to focus on testing interval



The results of the disconnection of these inverters show they followed a standard response consistent with the standardised response described in AS/NZS 4777.2. It is noted that the day of the test was actually a very cloudy and wet weather day for these sites, and the DPV output was much lower than expected on a sunny day. Figure 9 below demonstrates that these selected sites were all generating different amounts before and after the tests, and that during the curtailment test all DPV sites clearly ceased generating.

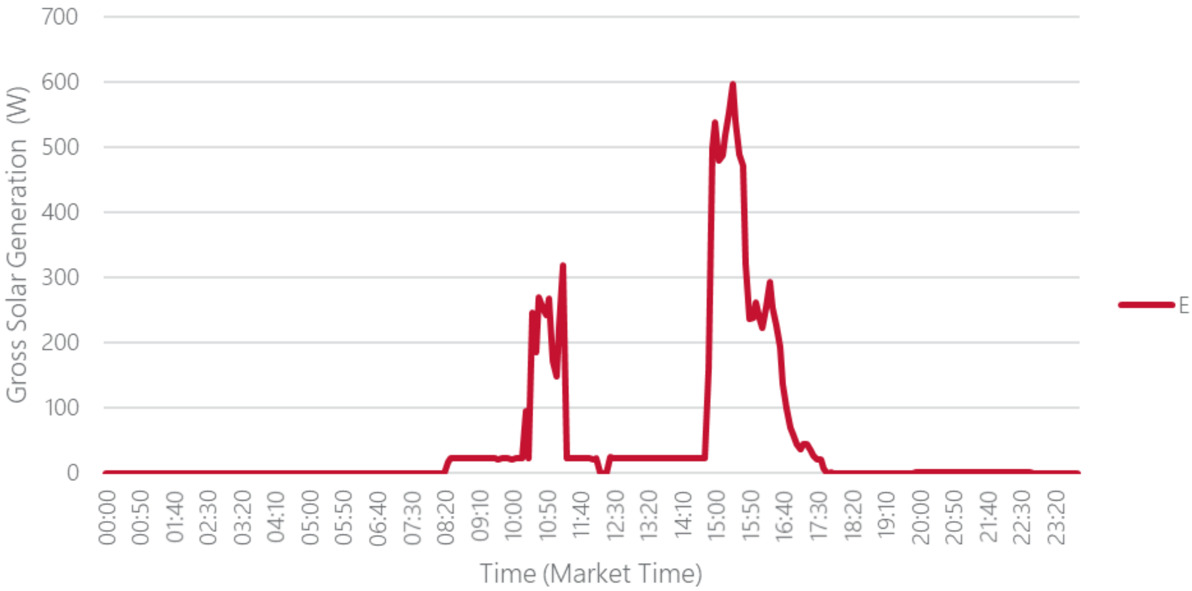
Figure 9 Gross DPV generation as measured by a number of sites within the trial



One of the test sites was operating in zero export mode when the tests were activated. The monitoring of this site under the trial demonstrated this mode was functioning correctly. Prior to the test, load at the site increased and the data shows a corresponding increase in the DPV output, without breaching its zero-export limit. This also occurred after the test, with these load changes both shown in Figure 10 below. Such visibility made available under this trial is another example of the normal 'lack of visibility' of typical DPV installations.

Leading into this trial it was unproven how an inverter in export limiting modes would respond to a remote command for generation to be reduced. It can be seen in Figure 10 that while the system was operating in this zero-export mode, the DRM0 was still received by the DPV inverter and this system complied by disconnecting the inverter. This highlights the primacy of DRM0 and therefore assurance that, for properly designed inverters, the response will be achieved under any site operating modes.

Figure 10 Test site which had been operating in a zero export limiting mode when the tests were activated



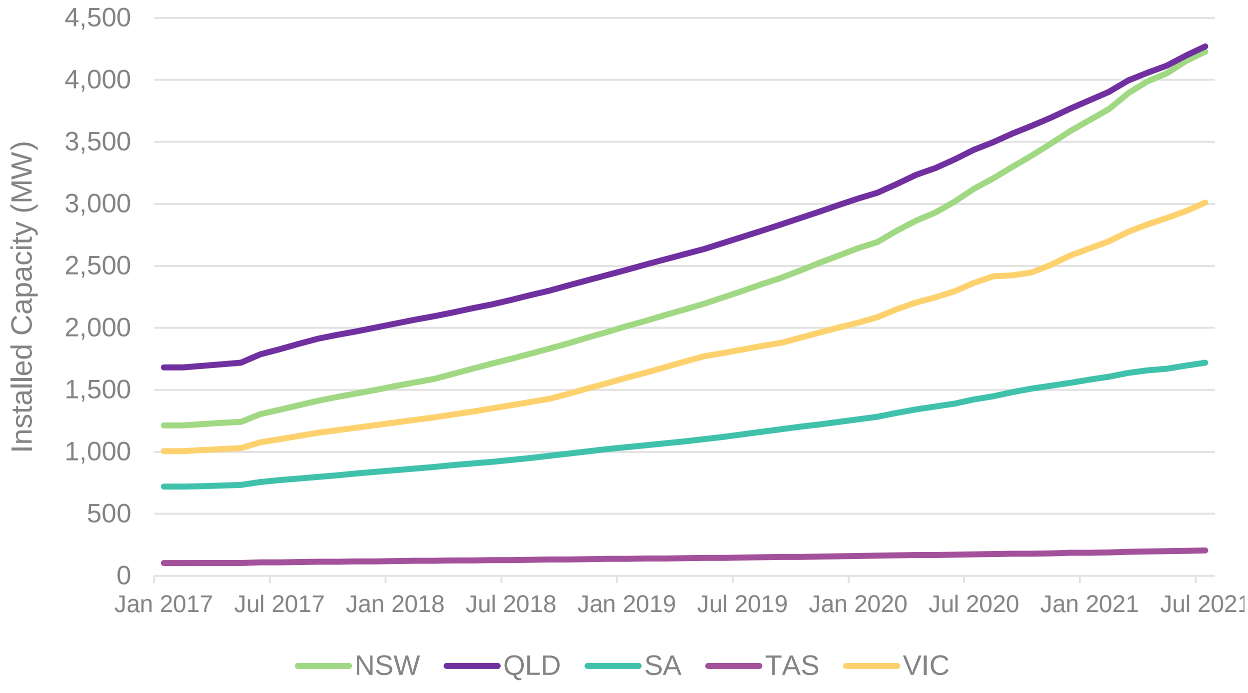
3.4 Aggregate DPV visibility

3.4.1 Context

As the penetration of inverter-based and behind-the-meter DER on the power system increases, enhanced visibility, forecastability and coordination are critical to AEMO's ability to ensure power system security is maintained. The growth of DPV presents a unique challenge, due to the currently limited real-time aggregate visibility of this generation source, while the generation acts to reduce operational or 'on-grid' demand, decreasing AEMO's scope of control.

Data during the 2020-21 financial year suggests the year had the strongest annual growth in DPV in the NEM to date, with an estimated 2,916 MW of NEM-connected systems below 100 kW installed. Figure 11 shows the estimated DPV installations per NEM region since 2017, illustrating the acceleration in installations.

Figure 11 Estimated DPV installations per NEM region since 2017



The DPV growth noted above, coupled with the increase in large-scale variable renewable energy (VRE) generation, is resulting in an unprecedented transformation of the electricity system. The transformation is increasing the power system's weather dependency, bringing with it increased challenges for short-term forecasting, both in the day-ahead and 'nowcasting' time horizons. Nowcasting refers to near-term, intra-day forecasts, where the current state of the power system can be used to better forward forecast the near-term conditions of the power system. AEMO's short-term forecasting provides a market signal, and projects the most likely scenario of outcomes in order for participants and asset owners in the market to decide on their preferred course of action. Metrics such as the level of demand or generation can quickly change after a forecast is produced, as a result of the forecast conditions.

To improve operational management under this new paradigm, the trial set out to test the benefits, if any, of a statistically valid sample of near-real-time gross DPV aggregate generation data in 'nowcasting' time horizons. AEMO currently uses aggregate near-real-time 5-minute DPV data in its nowcast; the hypothesis was to examine whether more data sets providing this information would materially improve the forecast, and AEMO's situational awareness of the operating state of the power system in the next interval. In relation to managing new power system operational challenges such as minimum system load, AEMO examined whether such additional data sets would improve real-time operational understanding as to whether security thresholds were in danger of being breached, and in turn the response required.

To do so, the visibility aspect of the trial used a sample set of 270 sites which followed the South Australian Government's 'Smarter Homes' requirements for a minimum two-element meter. Smart meters can have more than one metering element and contactor, and are therefore able to measure and operate several separate circuits independently. Historically (and outside of South Australia), DPV and household load are wired to the same element in a smart meter. To enable separate aggregate monitoring and independent management of DPV from the load, all that is required is for DPV to be connected to one of these separate elements of the smart meter. This wiring arrangement provides gross load, gross generation, and net load/generation. AEMO supports innovative or different options for meters or other devices to deliver such functionality at equivalent levels of quality.

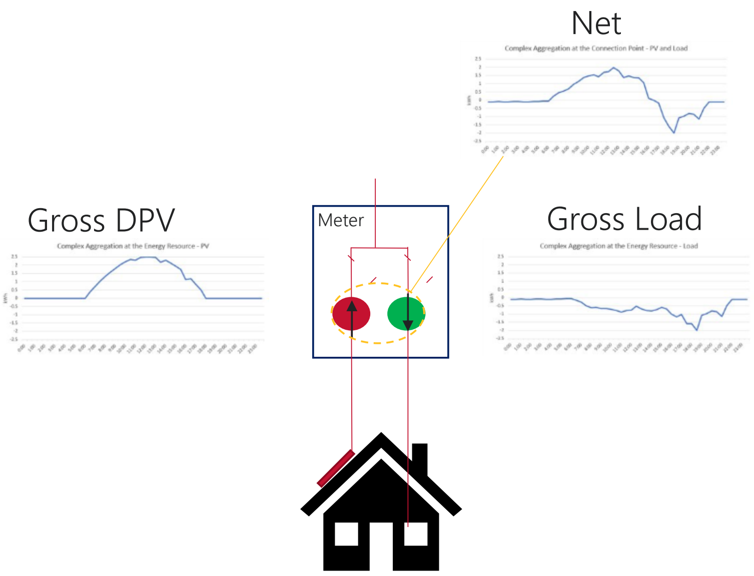
3.4.2 Data sets

Table 5 shows the data streams provided by the MC as part of the near-real-time visibility aspect in Phase 2.

Table 5 Details of the channels (data streams) from the smart meter provided by the Metering Coordinator as part of the near real-time visibility

5-minute energy data	Description	Element in Figure 12
Gross PV Generation at a site		
Import	Wh imported from the Grid for the PV on the Second Element	Red Element
Export	Wh exported to the Grid for the PV on the Second Element	
Gross Load at a site		
Import	Wh imported from the Grid for the site load on the Primary Element	Green Element
Export	Wh exported to the Grid for the site load on the Primary Element	
Net Generation/Load at a site		
Import	(Wh imported from the Grid for the site load on the Primary Element) – (Wh exported to the Grid for the DPV on the Second Element)	Yellow (virtual) Element
Export	(Wh exported to the Grid for the DPV on the Second Element)-(Wh imported from the Grid for the site load on the Primary Element)	

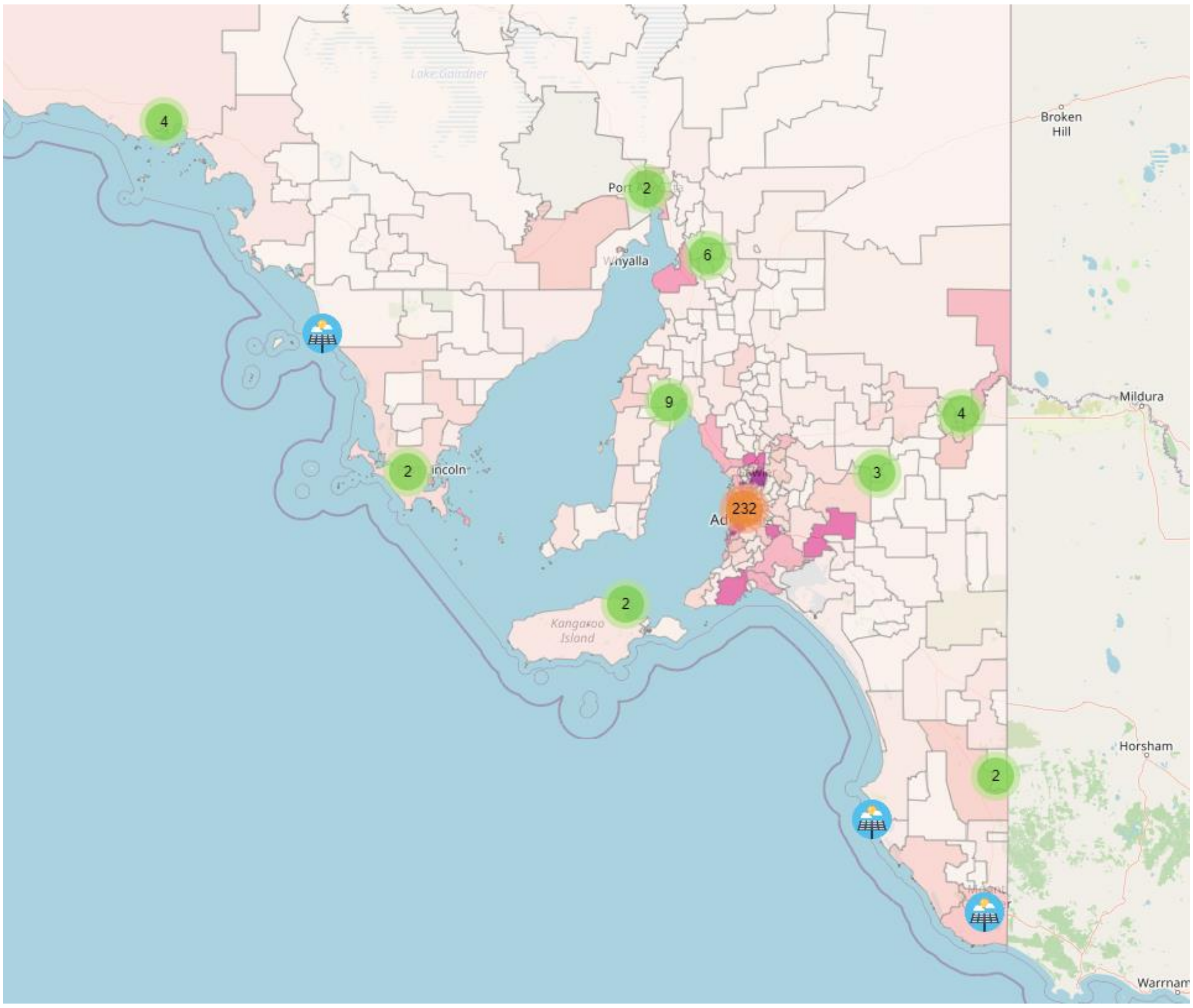
Figure 12 Figure of metering arrangement



3.4.3 Sample location

The trial provided statistically relevant data sets. Where postcodes had high levels of DPV, the number of meters within these postcodes reflected the larger number of DPV installed. This produced a sample which reflected the locations proportionately to the amount of DPV installed. This spread of the sample across the South Australian region is shown in Figure 13 below.

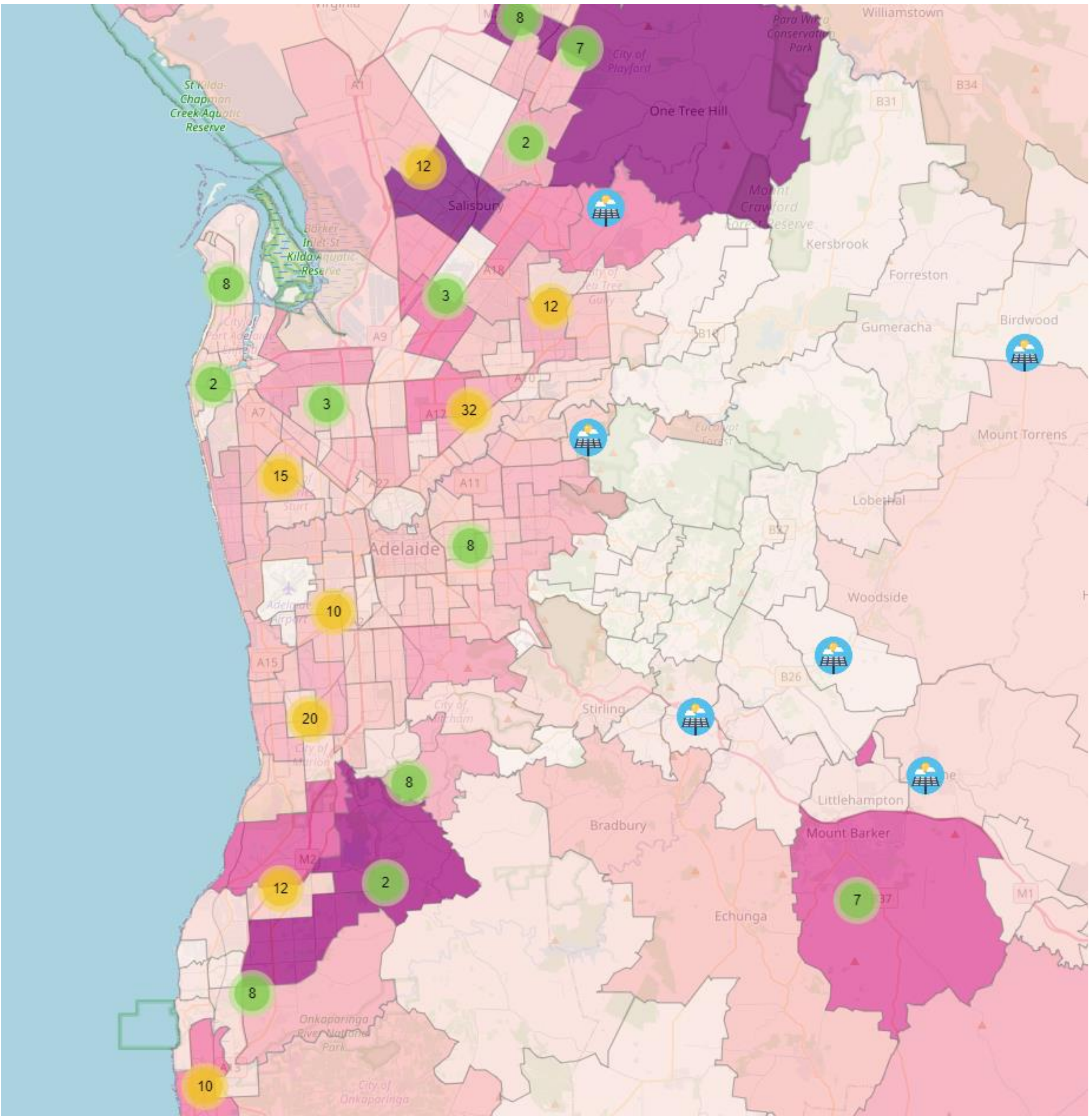
Figure 13 Locations for the sample set of the near-real-time metering sites across South Australia



Statistical relevancy is critical to forecasting, because the input data must be representative of the broader population, otherwise the forecast will not be reflective of the actual response. Delivering statistically valid data from across the DPV fleet is challenging. There is no way to understand the size of additional DPV systems or when they will be installed in any given region. A consistent approach to the installation of DPV allows additional data sites to be remotely activated to maintain statistical relevancy and therefore forecasting accuracy.

Figure 14 below is an expanded view of the cluster of the 232 meters within the greater Adelaide region, showing granularity of the meters in the trial.

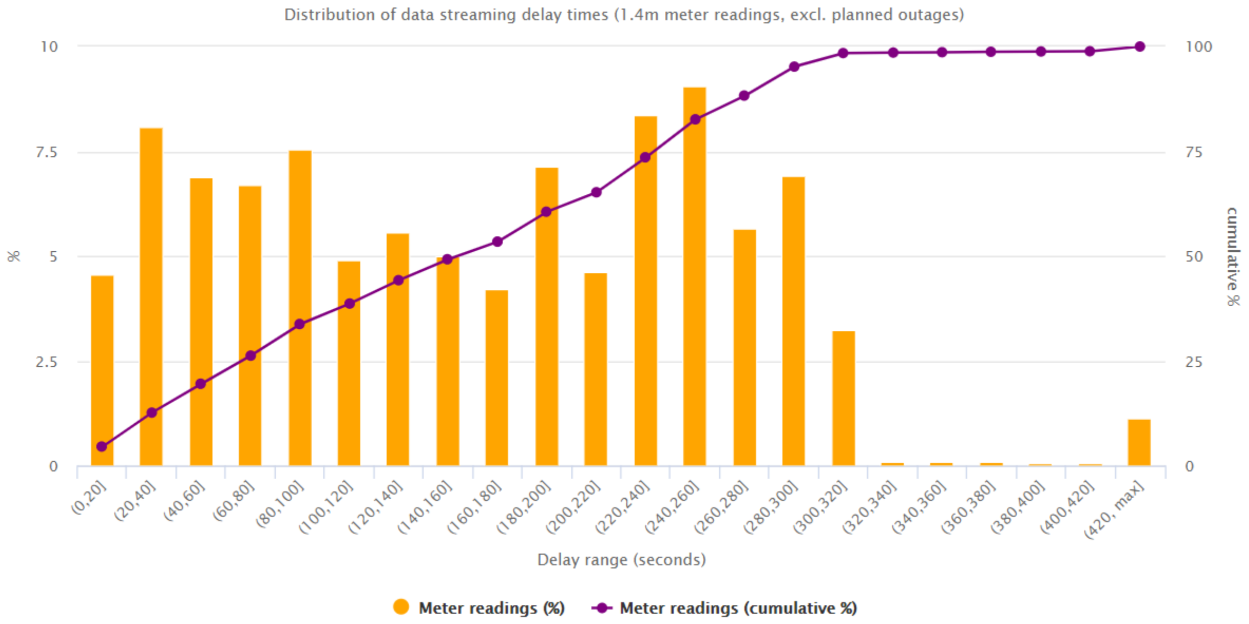
Figure 14 Locations for the sample set of the near-real-time metering sites across Adelaide



3.4.4 Data collection speed

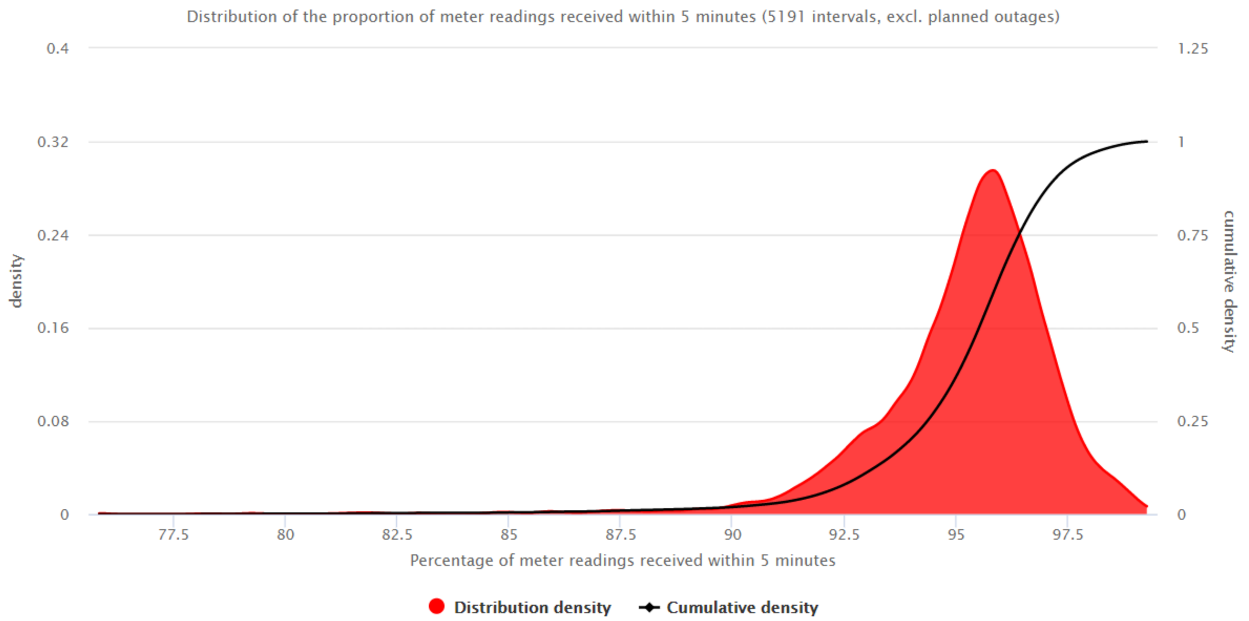
The data was read by the MCs and posted to a cloud storage location in a standardised format within tables which could be supported by several MCs. This aggregate data was retrieved from the cloud storage using standardised APIs which supported authentication, authorisation, and encryption cyber-security principles. AEMO polled this data storage periodically every 5 minutes. Over the course of the trial, AEMO analysed the timeliness of the data. Figure 15 below demonstrates the data was able to be loaded into AEMO's system and that 50% of data arrived within 140 seconds of the end of the previous 5-minute interval.

Figure 15 Overview assessment of the time taken for the data to arrive to AEMO



Another way of understanding the speed in which the data landed is via the distribution of the proportion of meter readings received within 5 minutes, as shown in Figure 16. This means that on average 96% of metering values were received before the start of the next 5-minute interval. It is noted that the solution has not been ruggedised and has been provided as a proof of concept without any guaranteed service levels and it is considered that these results would be improved if this was not the case.

Figure 16 Distribution of the proportion of meter readings received within 5 minutes



During the trial, two communications outages occurred resulting in the near-real-time data being unable to be retrieved by AEMO:

- One of these outages was planned, with the MC scheduling the outage with AEMO prior to the outage taking place. On recovery of the system, information from these meters during the outage period was backfilled. This backfilling process required more than 25,000 datapoints (the outage was from 8:15 am to 4:25 pm) to be recovered; results show that 99% of this data landed with AEMO in under 7 minutes, as shown in Table 6.
- The other outage was an unplanned loss of internet connection on the AEMO side. This resulted in AEMO systems being unable to connect and retrieve data using APIs; however, the MC was able to process the data into the data store as usual. Following the re-establishment of the connection to the internet, AEMO was able to backfill this missing data into systems at a much faster process time.

This data trial took place over just one month. Learnings from AEMO's Virtual Power Plant demonstration have shown that communications can fail over a period of time (for example, API updates resulting in failure in communications). This highlights the benefits of having redundancy in connections.

Table 6 Outage recovery and backfilling process following planned outage (13 June 2021, 8:15 am to 4:25 pm)

Load Time	Percentage of Readings	Number of Readings	Percentage of Recovered Data from Outage	Cumulative Total for Number of Readings
13/06/2021 16:25	6.2	1602	6.2	1602
13/06/2021 16:26	17.6	4554	23.8	6156
13/06/2021 16:27	15.1	3890	38.9	10046
13/06/2021 16:28	21.2	5483	60.1	15529
13/06/2021 16:29	22.6	5827	82.7	21356
13/06/2021 16:30	15.8	4084	98.5	25440
13/06/2021 16:31	0.4	96	98.9	25536
13/06/2021 16:32	0.4	96	99.3	25632
13/06/2021 19:06	0.4	96	99.6	25728
14/06/2021 11:14	0.4	96	100.0	25824

3.4.5 Benefits of near-real-time aggregate DPV data

The six aggregate data-streams or channels from the smart meters significantly improved understanding and situational awareness of power system operations in near-real time. The aggregate of gross generation, coupled with gross load, provided additional visibility of self-consumption. This gross and net visibility has a high correlation with regional native and operational demand respectively. This in turn provided greater situational awareness on current system conditions and changes to system conditions, and potentially helped identify the causes of the changes. Such understanding is unknown from data feeds from sites which have only net energy flows.

Figure 17 below plots aggregate gross site load and DPV data and site net energy flows. This is an important tool for the validation and situational awareness of both native demand and operational demand as well as real-time power system state estimation.

Figure 17 Aggregated gross site load and DPV data and site net energy flows

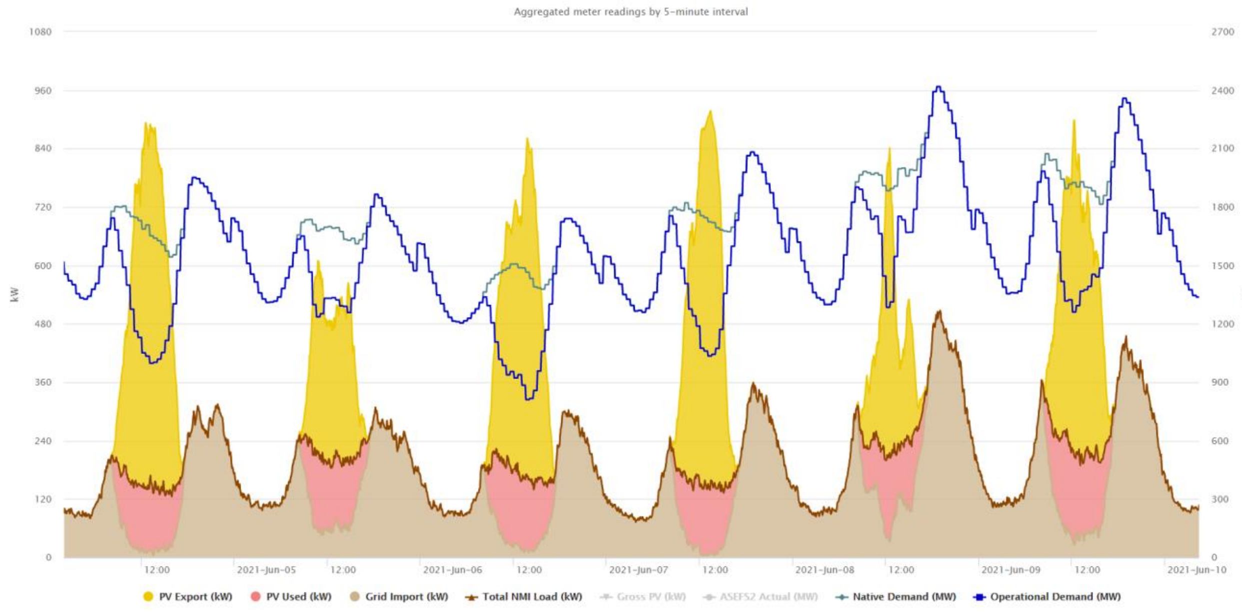


Figure 18 below demonstrates how this more timely data, which produces aggregate near-real-time native and operational demand, improves forecasting of these critical measures for keeping the power system in a secure operating state.

On 10 June 2021, there were a number of clouds moving across the South Australian region. These clouds produced intra-day variabilities that can be seen in the comparison between the upscaled trial data, and AEMO's estimate of gross DPV generation for the South Australia region from its existing forecasting tool, the Australian Solar Energy Forecasting System 2 (ASEFS2)[14], which includes all sites <100 kW).

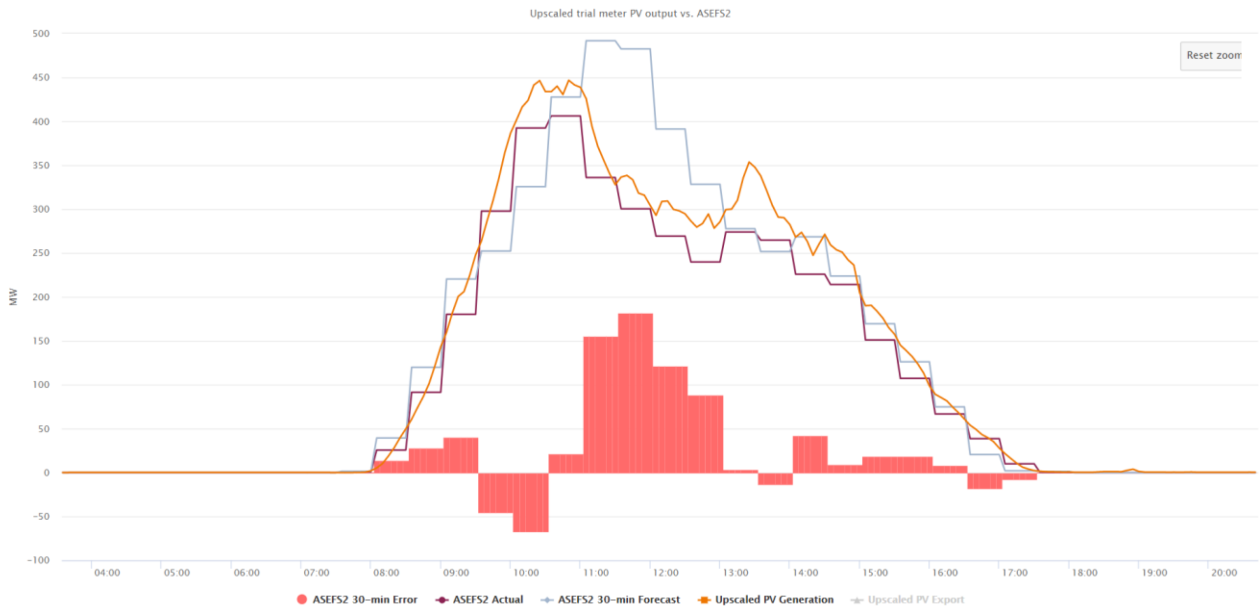
In Figure 18:

- The purple line shows the amount of DPV generation in the power system based on actual readings and calculated 30 minutes after real time.
- The light blue line is AEMO's ASEFES2 forecast without the additional metering data from this trial.
- The orange line is a forecast using the trial data, both calculated in near-real-time.

The additional 5-minute aggregate gross DPV data from the trial provides a more granular view of the variation in the system. On this day, forecast DPV deviated from estimated actuals by up to approximately 200 MW in some intervals, with enhanced real-time information (the purple line) helping near-term nowcasting in the DPV forecasts to improve accuracy.

[14] Available at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/operational-forecasting/solar-and-wind-energy-forecasting/australian-solar-energy-forecasting-system.

Figure 18 Upscaled trial data for 10 June 2021 coupled with ASEFS2 forecast and estimated actual DP



This speed, statistical relevance, accuracy, and reliability helps account for cloud formations over geographically small metropolitan areas, and the high variability and uncertainty of DPV generation these natural changes create. Without improved accuracy in forecasting and understanding of the variability and uncertainty in aggregate DPV behaviour as penetration increases, AEMO considers it will not be able to efficiently manage these fluctuations and configure the power system in a way to maintain security and ensure the most efficient outcomes for consumers.

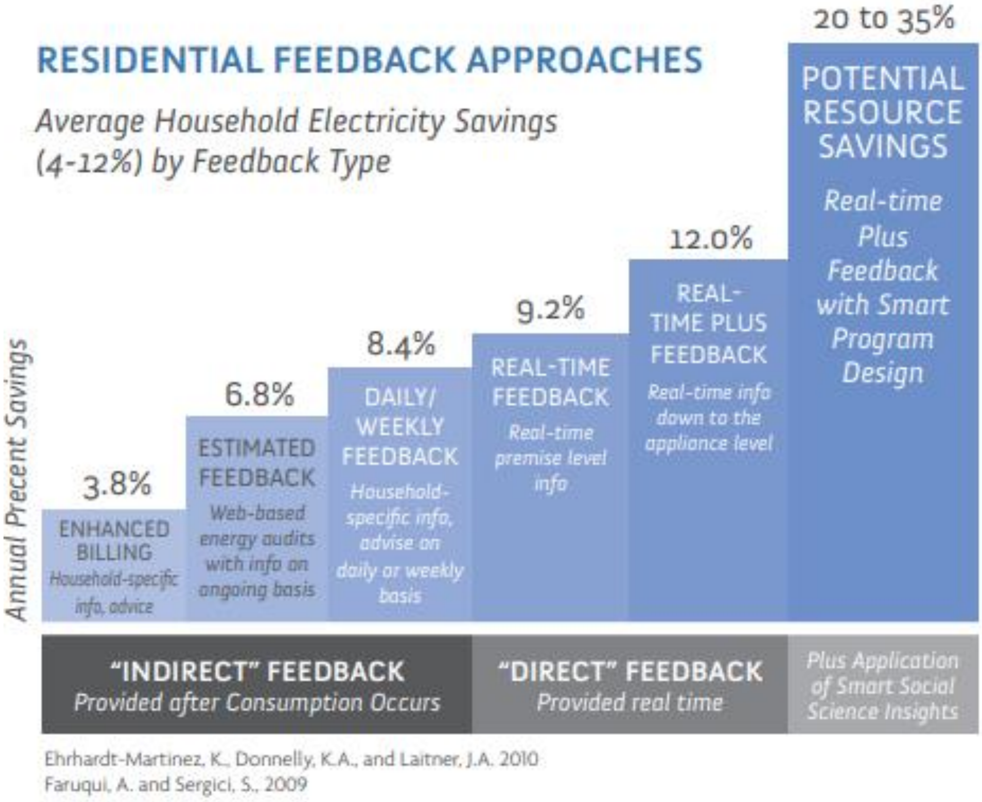
3.4.6 Consumer benefits of near-real-time gross DPV data

While AEMO was provided aggregate data of net DPV generation within this trial, this capability enables consumers to be provided with their individual net DPV production and net load consumption information, in real time. Typically, consumer billing information contains only the net behaviour of household devices, and consumers are unable to see the individual benefit of DPV against their household load, and in turn the true benefit or bill impact of load shifting behaviours. Separating DPV and load data, makes this information visible in billing information for the first time, and could also be made available to the consumer in near-real time.

The benefits of such disaggregated information are significant, in that they enable consumers (including those without DPV) to make better decisions and better manage their energy bills. Literature reviews of more than 50 studies relating to energy data access found the more granular and timely the energy information, the greater the savings to the consumer[15]. As shown in Figure 19 below, gross appliance level information in real time delivered savings in the order of 12%, increasing to 35% when this level of disaggregated information was combined with 'Smart Program Design' such as emails or text messages to consumers suggesting a voluntary response.

[15] See https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/operational-forecasting/solar-and-wind-energy-forecasting/australian-solar-energy-forecasting-system.

Figure 19 Correlation between information timeliness, net energy data and consumer savings[16]



3.5 Event of 14 March 2021: Smart meters' response

On 14 March 2021, AEMO issued an instruction that operational demand in South Australia be maintained above the minimum level required to ensure the power system remained in a secure operating state. This instruction resulted in SA Power Networks activating 'Smarter Homes' requirements for the first time, resulting in the registered Relevant Agents curtailing a small amount of DPV for a short time. AEMO has published a separate, detailed report into this event[17]. This part of the Phase 2 trial specifically reviewed the response of smart meters in activating DPV curtailment.

Following the event, AEMO analysed an aggregate dataset of 150 sites that used meters to activate the DPV response. The dataset included smart meter 30-minute interval consumption data across all these sites.

These aggregated responses can be seen in Figure 20 below.

Analysis of this data provided clear indication of 80 sites switching off on average 3.75 kW of DPV generation.

Review of another 70 sites within this dataset demonstrated no response to the signal, as the aggregated export of energy from these sites into the grid did not have the step change as shown in the other 80 sites. These sites appear to have been commissioned incorrectly. Discussions indicate this may have been due to confusion with

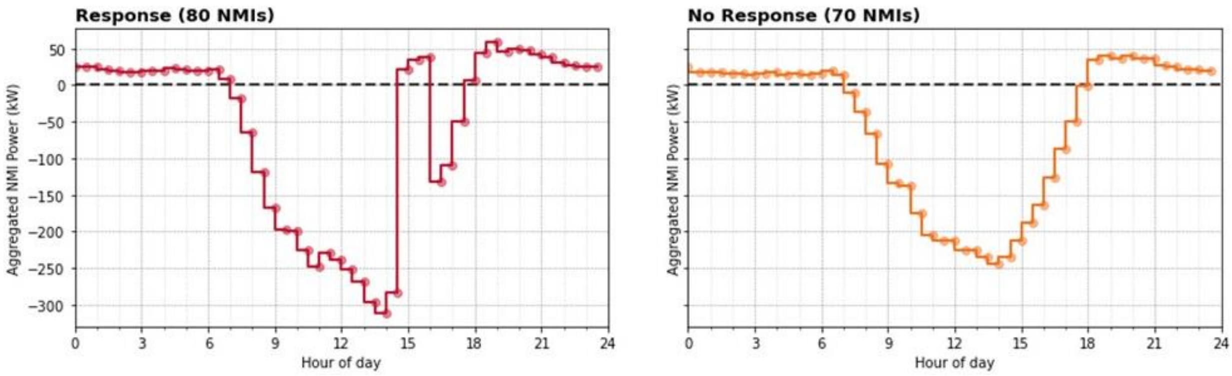
[16] See https://static1.squarespace.com/static/52d5c817e4b062861277ea97/t/56b2ba9e356fb0b4c8559b7d/1454553838241/Got+Data+-+value+of+energy+data+access+to+consumers.pdf and https://www.aceee.org/sites/default/files/publications/researchreports/e105.pdf.

[17] Available at xxxx.

installers on the actual date for, and different methods of, compliance to the new requirements. These work practices have been updated and rectification actions are underway.

Regardless of the commissioning learnings which impacted the physical response of the systems, during the 14 March 2021 event around 98% of meters were successfully communicated with. Some minor expected communication issues occurred with a few sites; these were immaterial to the fleet response and within the range experienced during Phase 1.

Figure 20 Aggregated response from 150 sites during the system event on 14 March 2021



The response from smart meters follows the shape and response as with other DPV systems that responded during the 14 March 2021 event to support power system security. A sample response from 7,762 sites averaging 1.7 kW of DPV generation can be seen in Figure 21. The graph on the left includes both Relevant Agents and Enhanced Voltage Management (EVM) used by SA Power Networks, with the right graph showing sites demonstrating no response or change in DPV output in related to this system event.

Figure 21 Sample set providing an indication of the aggregated response across Relevant Agent and Enhanced Voltage Management (EVM) used by SA Power Networks for the system event on 14 March 2021

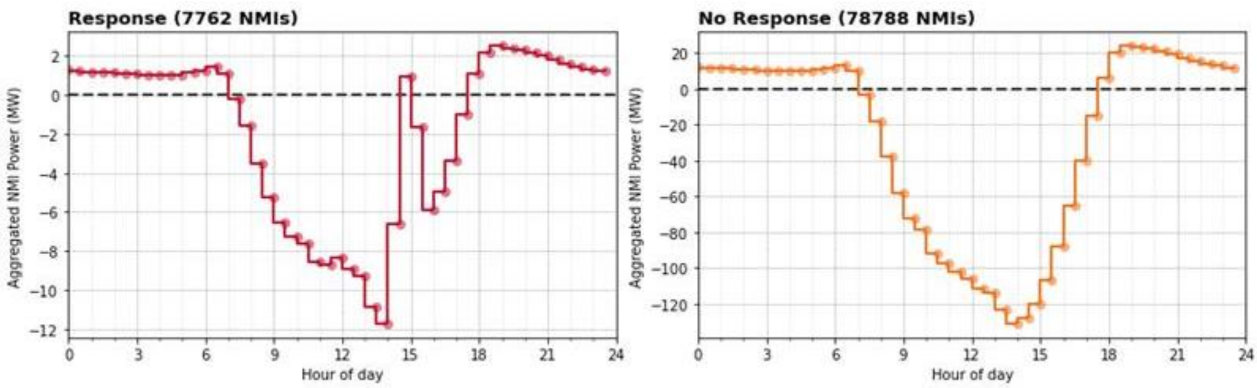
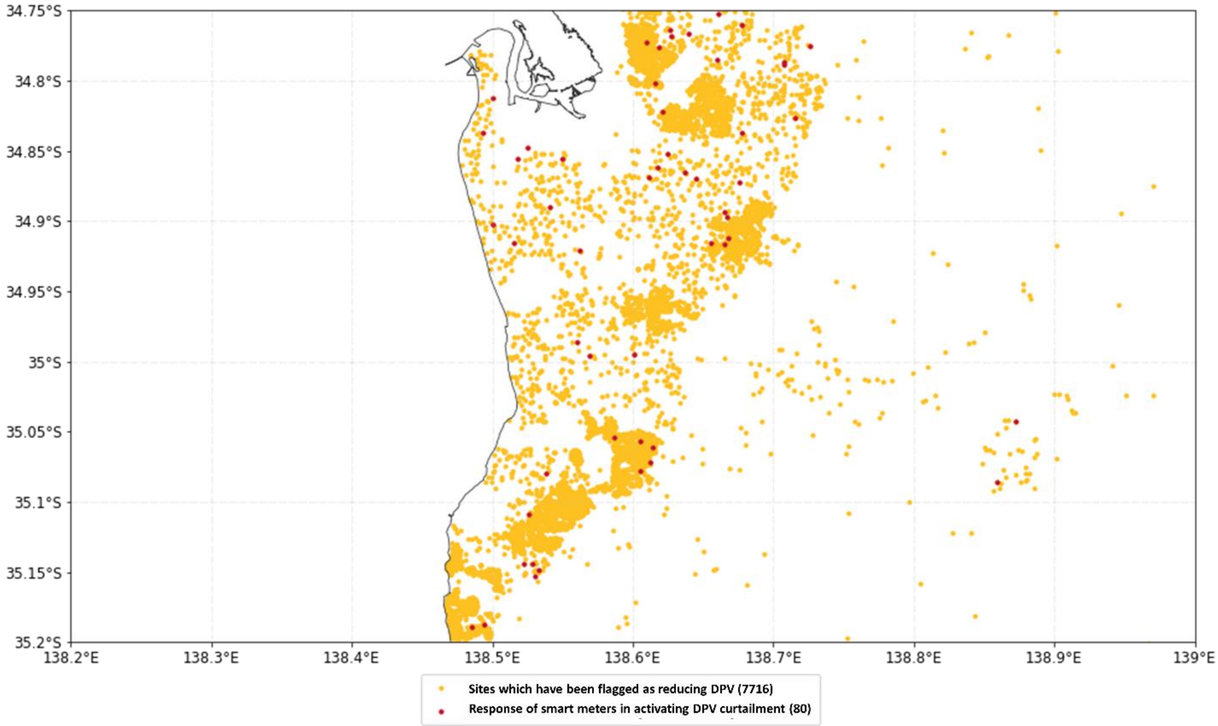


Figure 22 below examines the EVM response on 14 March 2021. This assessment was undertaken by analysing data from remotely read interval meters which were flagged as having DPV. The sites which showed a reduction in DPV via EVM and other 'Smarter Homes' arrangements were mapped across the greater Adelaide area. In Figure 22, the seven substations which utilised EVM are clearly identified, as they appear via several clusters. The figure also shows the smeared response of other DPV curtailed outside of the EVM substations, via the capabilities of 'Smarter Homes' to individually manage these systems.

This information is currently not available to the control room in near-real-time. As shown in Section 3.4, understanding of both loads and generation in near-real time can improve situational awareness. Near-real-time visibility of DPV, coupled with knowledge of the operational modes of DPV (such as curtailments currently active and their aggregate outcome), is necessary to ensure situational awareness is maintained and enable the accurate reconstitution of the demand forecast.

Figure 22 Mapped Aggregated response across Enhanced Voltage Management (EVM) Zone Substations and Relevant Agent for curtailed DPV system during the event on 14 March 2021



3.6 Key learnings of Phase 2

Further detail to the key learnings from Phase 2 of the trial, as detailed in the Executive Summary, are summarised below. The trial:

- Demonstrated that aggregate near-real-time visibility of 5-minute energy data from smart meters could be delivered and utilised within a fast response time.
- Tested a recovery process which was successful for the backfilling of data following planned and unplanned system outages.
- Proved a standardised solution for mapping aggregate visibility of DPV response over both a region and network level is easily possible, is possible using reliable, existing, accurate, measurement precise, trade law certified, low cost ubiquitous technology, and possibly regardless of the technology used to control DPV.
- Demonstrated that current forecasting has some constraints with natural variation in cloud coverage which can create intra-day variability in the demand forecast that can be mitigated with further data sets.
- Showed that aggregate 5-minute metering data from smart meters can be provided to AEMO without additional devices, communication modules or reliance on consumer internet access.

4 Next steps options

The outcomes of this trial highlight key focus areas for further investigation:

- Actualising the potential for similar protocols to be used for gaining visibility over DER to provide consumers with better data and in aggregate to support power system and network operators in balancing supply and demand in a high DER power system.
- Considering the results of this trial in the ESB's Post 2025 program, which is currently undertaking a market design process including how to activate 'two-sided markets'. The ability for DER to engage in markets for system balancing services, and the results of this trial, will be considered throughout that design process.
- Trialling to test the ability for this technology to assist in under frequency load shedding (UFLS), over frequency generator shedding (OFGS), and system restart ancillary services (SRAS) capabilities.
- Exploring what markets can be enhanced with these "new" capabilities – review current market offerings providing pool-price exposure including a potential demand response trial for measurement and visibility.
- Considering advanced operational techniques this technology could enable that minimise the number of consumers effected when managing system security risks. A scope for another trial could include selecting to disconnect DPV on the basis on their actual net export (that is, leave systems on which are net load). This would require new capabilities; SA Power Networks indicated it would be interested in exploring this.