



# MicroGrids and Associated Technologies

**April 2018**

**Opportunities and challenges for power system and  
market operation**

A submission to the Economics and Industry Standing Committee

# Important notice

## PURPOSE

This is AEMO's submission to the Economics and Industry Standing Committee's inquiry into MicroGrids and associated technologies in Western Australia.

This publication has been prepared by AEMO using information available as at 5 April 2018.

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# Executive Summary

The Australian Energy Market Operator (AEMO) appreciates the opportunity to make a submission to the Economics and Industry Standing Committee inquiry into MicroGrids and associated technologies.

Similar to other markets, including the National Electricity Market (NEM), the Wholesale Electricity Market (WEM) is seeing supply resources shifting away from fossil-fuel generation towards a diversity of firm, intermittent and peaking generation, both large-scale and at the residential level.

Consumer engagement is at an all-time high with solar panels installed on one in four household roofs in the South West Interconnected System (SWIS).

As the market and system operator for both the NEM and WEM, AEMO has observed that the growth of Distributed Energy Resources (DER), including residential solar panels, is materially affecting AEMO's ability to deliver power system security and supply reliability.

Provided that the right changes are made to technical, regulatory and market frameworks, MicroGrids can be used to effectively integrate active consumers into the power system as it evolves to a low carbon electricity network.

Where sufficient visibility of DER can be achieved and practical coordination mechanisms for DER are implemented, the capacity afforded by DER (either as part of a MicroGrid or otherwise) can be leveraged to achieve power system security and resiliency, as well as market objectives. The resulting benefit to consumers will be an overall reduction in energy costs while enabling customer choice and the decarbonisation of the electricity network.

The objective of any MicroGrid-related reform should therefore be to facilitate a broad range of opportunities in regard to new business models and technologies, market development, and new approaches to power system and market operation and planning. The potential benefits of getting this right are significant. Any benefits, however, will be far outweighed by the consequences of not managing the adverse impacts of this new technology to the security and reliability of the power system, and to market effectiveness. Simply put, DER and MicroGrids currently represent the greatest opportunities but also the greatest challenge to the power system.

The opportunities afforded by DER and MicroGrids can only be realised through an understanding of their capability and an understanding of the technical and operational requirements of the power system as it evolves. The design of the power system and the electricity market can then be structured to facilitate an affordable, secure, reliable and low-emissions energy future for all Australians.

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# 1. Introduction

## 1.1 About AEMO

AEMO is responsible for operating Australia's largest gas and electricity market and power systems, including the National Electricity Market and Wholesale Electricity Market.

AEMO's role in relation to energy markets and systems involves working with jurisdictional governments and providing advice to ensure that markets are responsive to energy sector needs, with the objective of supporting the long-term interests of consumers.

AEMO undertook the role of independent energy market operator (market operator) for the WEM and power system operator (system management) in Western Australia from November 2015. This role includes ensuring that the power system achieves reliability and security levels that customers value now and in the future as the energy system transitions to a more dispersed variable supply. The role also includes making day-to-day assessments of the adequacy of the power system to deliver supply within system limits and making longer-term forecasts of adequacy.

## 1.2 Purpose of this document

This document is AEMO's submission to the Economics and Industry Standing Committee inquiry into MicroGrids and associated technologies, which is investigating:

- 1) The potential for MicroGrids and associated technologies to contribute to the provision of affordable, secure, reliable and sustainable energy supply, in both metropolitan and regional Western Australia.
- 2) Opportunities to maximise economic and employment opportunities associated with the development of MicroGrid and associated technologies.
- 3) Key enablers, barriers and other factors affecting MicroGrid development and electricity network operations.
- 4) Initiatives in other jurisdictions to facilitate the development, and maximise the value of, Microgrids and associated technologies.

AEMO's submission focuses on items 1 and 3 of the inquiry, and at a power system rather than network level, for the following reasons:

- As the market and system operator, AEMO's experiences in managing the system place us in a unique position of understanding the requirements for a secure and reliable system.
- AEMO's expertise relevant to MicroGrids, and the DER that enable them, is in market and system operations of larger power systems, and therefore the connection of MicroGrids and DER to these large grids, rather than standalone applications.
- As the power system operator (rather than network operator, which is Western Power in the SWIS) AEMO's exposure to MicroGrids (and specifically DER) is at the system level. However, AEMO recognises that MicroGrids present challenges and opportunities across the entire electricity supply chain.

Consequently, AEMO's submission does not cover in the same level of detail, in the context of a competitive retail market, time of use metering, and smart metering or other smart connection arrangements, although AEMO acknowledges that these arrangements have an impact on the rate of penetration of MicroGrids and DER. However, AEMO considers that progression of MicroGrids and DER will provide opportunities with regard to electricity retail and power system operation which can be realised through smart metering and other innovative energy trading approaches, such as blockchain.

AEMO's submission addresses its ability to manage the impact of MicroGrids with DER on the power system in the SWIS. In doing so, AEMO frames this response in terms of AEMO's responsibilities as the power system operator, giving particular attention to the level of its visibility into the power flows associated with MicroGrids with DER. The submission also covers the market implications of MicroGrids with DER, the implication of 'doing nothing' and how market mechanisms might best be leveraged to integrate MicroGrids with DER to ensure that consumer choice, energy affordability, power system security and reliability, and environmental benefits are optimised.

### 1.3 The rise and rise of DER

Figures 1 through 3 below, which are taken from AEMO's 2017 Electricity Statement of Opportunities for the WEM<sup>1</sup> (WA ESOO), show our ten-year forecast (low, expected and high scenarios) from 2017-18 to 2026-27 for the uptake of rooftop solar PVs systems, battery storage systems and electric vehicles.

**Figure 1 - Installed rooftop PV system capacity, 2017-18 to 2026-27 financial years**

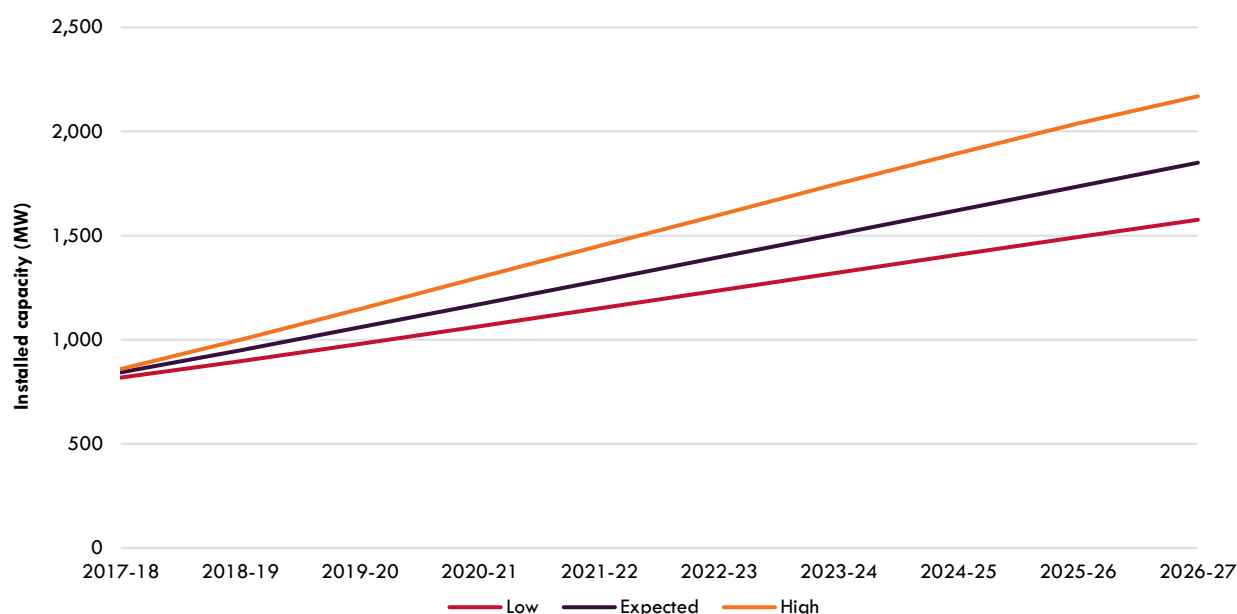
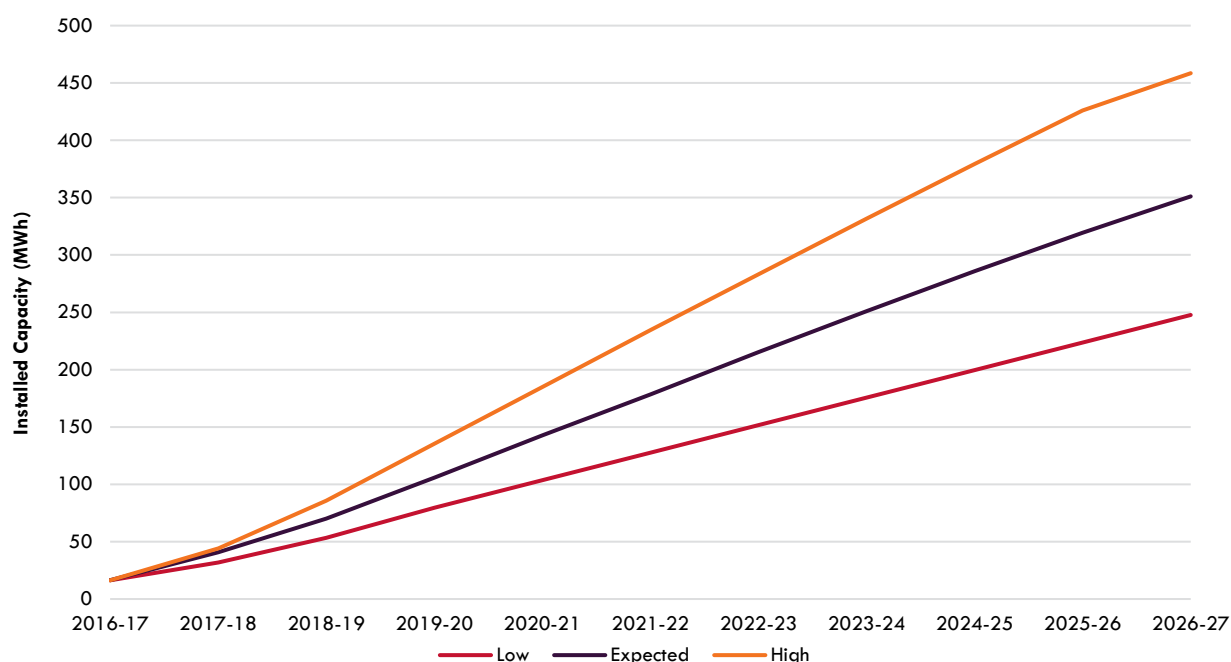


Figure 1 shows stronger growth rates for rooftop solar PV capacity across all scenarios than the earlier forecasts presented in AEMO's 2015 WA ESOO for the WEM.

<sup>1</sup> AEMO (2017), 2017 Electricity Statement of Opportunities for the Wholesale Electricity Market, June.

**Figure 2 - Installed capacity of battery storage systems, 2017-18 to 2026-27 financial years**

The 2017 WA ESOO forecast for the installation of battery storage systems includes small-scale residential and commercial customers only, and excludes grid-scale systems used for energy arbitrage or network stability purposes. Substantial growth is expected in all scenarios.<sup>2</sup>

The forecast rises in rooftop solar PV systems and battery storage systems is due to various reasons including decreasing costs of these technologies, increasing consumer awareness of these technologies, higher electricity tariffs and sustainability considerations.

AEMO's projection for electric vehicle uptake assumes a slow start due to limited infrastructure, the narrow range of models currently available, and the cost relative to conventional petrol or diesel vehicles.<sup>3</sup> While growth is expected in all scenarios, the range between the high and low forecasting cases is quite wide due to uncertainty around decisions on industry policy, such as vehicle fleet emission standards, which could influence electric vehicle uptake.

<sup>2</sup> AEMO engaged Jacobs to forecast the installed capacity of small-scale grid connected battery storage systems in the SWIS. This is the same approach as that taken for forecasting battery storage in the NEM for AEMO's 2017 *Electricity Forecasting Insights*, available at <https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Electricity-Forecasting-Insights>

<sup>3</sup> AEMO engaged an external consultant to forecast the energy consumption of electric vehicles on future energy demand. The forecasts presented in this section are taken from *AEMO Insights: Electric Vehicles* <http://aemo.com.au/Media-Centre/AEMO-Insights---Electric-Vehicles>

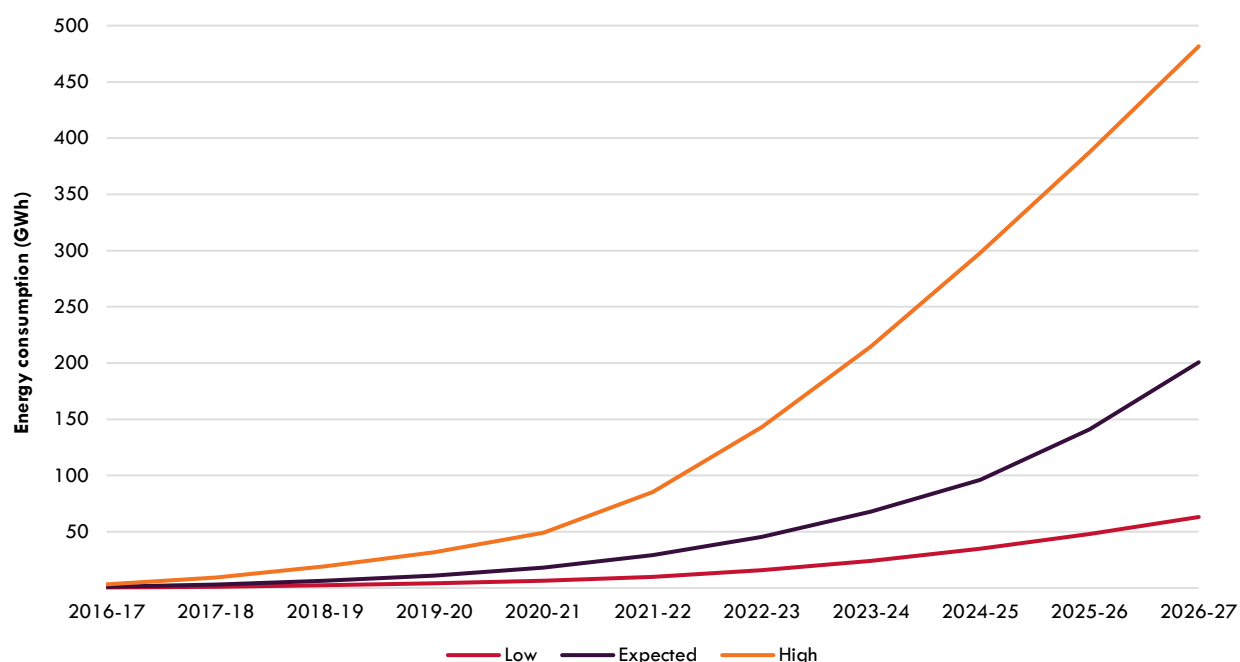
**Figure 3 - Electric vehicle contribution to operational consumption, 2016-17 to 2026-27 financial years**

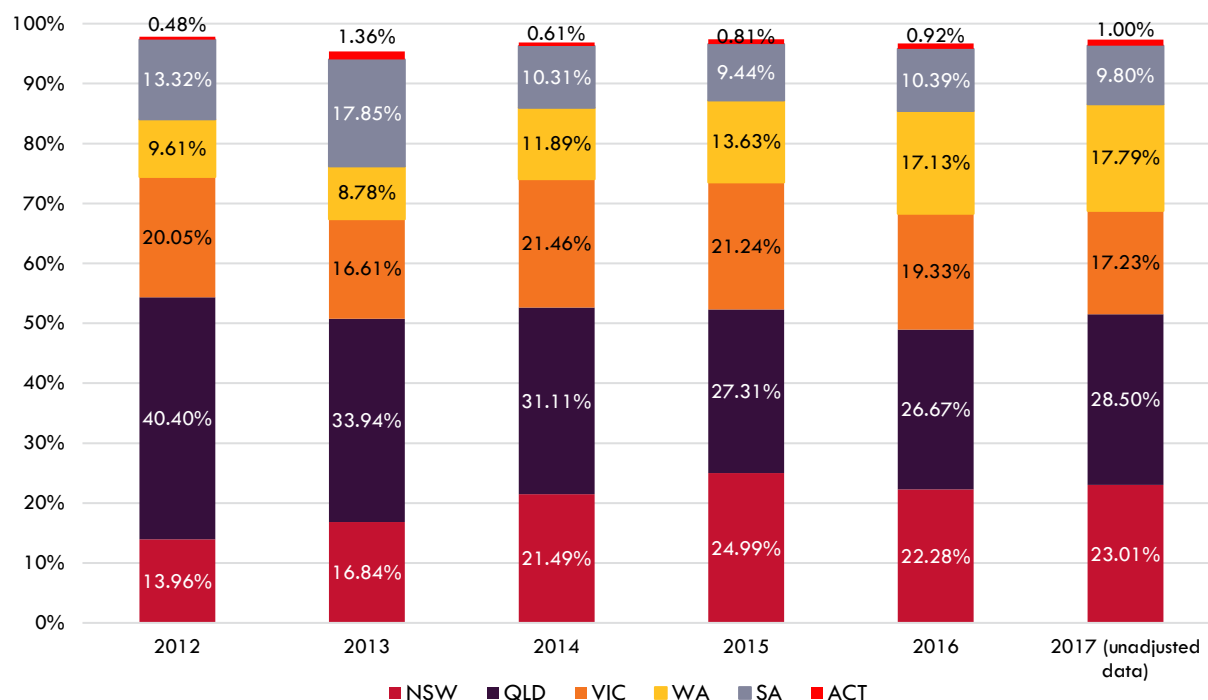
Figure 4, which is taken from the Clean Energy Council's *Solar Report* confirms that Western Australia has experienced an increasing share of national rooftop solar PV capacity since 2012.<sup>4</sup>

Similar to the WEM, the NEM also has a large penetration of installed rooftop PV, with Queensland and South Australia having the highest proportions of the National Electricity Market regions. This level of local renewable generation is close to the limit of the 30 to 50 per cent band identified by the International Energy Agency and cited by the Energy Security Board<sup>5</sup> as the level at which technical challenges can be expected to arise.

<sup>4</sup> Clean Energy Council (2018), *Solar Report*, January.

<sup>5</sup> Energy Security Board (2017), *The Health of the National Electricity Market*, Annual Report, p.25. See <http://www.coagenergycouncil.gov.au/publications/health-national-electricity-market-report>



**Figure 4 - Proportion of yearly solar PV installed capacity across Australian jurisdictions**

Source: Figure recreated from Clean Energy Council (2018) *Solar Report*, January, p.5, using Clean Energy Regulator data, Australian Energy Council analysis. Note that year totals do not total to 100% due to rounding.

Lessons learnt from our operation of the power system in the NEM can be similarly applied to the WEM in understanding the intrinsic challenges and opportunities associated with managing a large interconnected power system with high levels of DER.

Unlike the regions within the NEM, the SWIS in Western Australia is an islanded system which means it has to be self-sufficient. For example this means it cannot import generation from other regions if DER output is low. Alternatively, any surplus from generation from rooftop solar PV systems cannot be exported either. As a result, in the SWIS, technical limitations will arise sooner than if it was interconnected as part of a larger network.

With the penetration of DER at significant levels and forecast to grow into the future, it is critical to understand the opportunities and challenges of these technologies.

## 2. Understanding MicroGrids

MicroGrids come in various configurations according to their function, that is, according to what problem the MicroGrid is installed to resolve. All configurations in the SWIS - NanoGrids, embedded networks and fringe-of-grid solutions - contain some level of DER and all are connected to Western Power's distribution network. Further, as they are connected to the distribution network, they are currently below AEMO's threshold of visibility and beyond AEMO's authority to coordinate.

In its 14 February 2018 transcript of evidence given to the Economics and Industry Standing Committee's inquiry into MicroGrids and associated technologies, the Public Utilities Office (PUO) discusses the various configurations of network elements and connected assets that comprise MicroGrid systems, and the drivers that have led to their up-take within the SWIS and regional Western Australia.

AEMO supports the PUO's observation that most MicroGrid configurations include DER such as rooftop solar PV systems and battery storage systems. Consequently, AEMO's submission focuses on the opportunities and challenges posed by MicroGrids with DER based on a functional description of MicroGrids. This functional description is generally aligned with the configurations identified by the PUO.

Where there is a sufficient level of visibility and coordination, DER presents opportunities and value to the power system as well as consumers. DER can refer to alternative generation such as rooftop solar PV systems and energy storage systems, as well as associated technologies such as electric vehicles, micro-wind turbines, home energy management systems and demand management. Consequently, DER are predominantly installed or located at a customer's premises.

To date, interest in DER has largely been motivated by engaged consumers through the installation of rooftop solar PV systems and increasingly, battery storage systems.

### 2.1 Why does 'visibility' and 'coordination' matter?

A MicroGrid is a small-scale power system that consists of distributed generation sources that are; linked in an intelligent communication and control system to supply power to distributed loads. They are usually operated autonomously to be part of the main electricity network or switched to be 'islanded' depending on their type and operational scenarios. Consequentially, MicroGrids can provide alternative solutions to traditional network asset management and reinforcement plans to increase reliability and security of the power system. By having a battery storage system as part of their generation mix, MicroGrids can also provide for demand management and energy arbitrage, although it is acknowledged that these two things cannot always be maximised concurrently.

The term 'visibility' refers to the power system operator's ability to monitor the status and indications of MicroGrids remotely in real-time for management, coordination, planning and security of the power system. The term 'coordination' refers to the ability of the power system operator to remotely manage the level of generation of DER. This can mean total disconnection or the management of regulation up and down of the generation to facilitate system security.

Under the Technical Rules, AEMO's visibility of MicroGrids can be, in certain circumstances, limited to facilities exporting 1 MVA<sup>6</sup> or more to the distribution network. Additionally, in certain circumstances, AEMO may lack visibility of MicroGrids that include generation units of more than 1 MVA in size when they export less than 1 MVA to the distribution networks. This in turn may represent a real power system security challenge to AEMO where more MicroGrids with DER of this composition become operational and the aggregate MVA quantity of MicroGrid capacity becomes more significant.

AEMO does not currently have the ability to coordinate DER or the generation elements within a MicroGrid containing DER. Without sufficient mechanisms for visibility and coordination, as DER proliferate across the SWIS, AEMO anticipates that there will be increased volatility in the load profile of the SWIS and a deterioration in the accuracy of its forecasts. This can affect the dispatch planning, power system security and market clearance price forecasts and hence market effectiveness.

As detailed in AEMO's *Visibility of Distributed Energy Resources*<sup>7</sup> report, DER will progressively affect AEMO's ability to manage supply and demand as it causes reduced visibility of the drivers of power flows and load volatility. This is exacerbated by the lack of price responsiveness of passive DER, which affects AEMO's ability to operate the power system securely and reliably. It also creates market inefficiencies as AEMO will be unable to deliver accurate information to participants.

Actions to make DER more visible to AEMO and the market will ensure that consumers will be better placed to embrace the opportunities provided by DER, and will enable the power system to be managed more efficiently through better operational processes and market signals. AEMO notes that a rule change request was submitted by the COAG Energy Council to the Australian Energy Market Commission on 6 March 2018 to establish a national register of DER (including small-scale battery storage systems and rooftop solar PV systems) installed in the NEM.<sup>8</sup> A similar initiative may be warranted for the SWIS.

## 2.2 Opportunities and challenges of DER

Realising the overall benefits of DER requires coordination and action across the energy industry to facilitate their effective integration. AEMO's objective is to optimise the opportunities presented by DER while maintaining a secure and reliable power system and effective electricity markets.

Achieving this objective requires an understanding of the technical capability and limitations of DER, how they are used, and appropriate visibility and integration into operational systems and processes. This is likely to require a combination of changes to regulatory and market frameworks, technical standards and operational processes. In particular, it will involve the appropriate coordination of DER, which will need to take into account the willingness of consumers to actively participate, necessitating a program of consumer engagement and awareness throughout the industry.

DER can be part of a number of different business models. While most DER are 'set and forget' some do participate in demand response.<sup>9</sup> The technical requirements for DER are set by Standards Australia, and individual installations are not currently registered with AEMO, nor do they participate in the central dispatch.

New MicroGrid developments have resulted in changing supply and demand curves (refer to section 1.3). Demand, which has traditionally been passive and relatively predictable, has seen consumers becoming more engaged with how they interact with the electricity network. While each

<sup>6</sup> MVA (Mega Volt Amps) is a measure of total power including MW (Mega Watt) and MVAR (Mega Var).

<sup>7</sup> AEMO. *Visibility of DER*, January 2017. Available at [https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security\\_and\\_Reliability/Reports/2016/AEMO-FPSS-program---Visibility-of-DER.pdf](https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Reports/2016/AEMO-FPSS-program---Visibility-of-DER.pdf)

<sup>8</sup> See <https://www.aemc.gov.au/rule-changes/register-distributed-energy-resources-retail>

<sup>9</sup> See <https://arena.gov.au/funding/programs/advancing-renewables-program/demand-response>

individual DER is small in terms of its practical effect on the power system, in aggregate they can have a material impact on the operation of the power system. Consequently:

- Supply not only has a controlled component at the utility scale, but also an increasing uncontrolled component due to the uptake of small-scale renewable generation at the distribution level.
- Demand not only retains a passive component, but also an increasingly interactive component due to the uptake of MicroGrids with DER that are not always visible to AEMO.

In Western Australia, DER may be deployed in the context of MicroGrids. How AEMO manages the impact of MicroGrids will largely depend upon the configuration of a MicroGrid and the type of DER contained within that MicroGrid.

## 2.3 Configurations of MicroGrids with DER

This section provides an overview of the main MicroGrid configurations that are being developed for practical operation in the SWIS. Examples for the NEM are provided by way of comparison.

The main similarity shared across all MicroGrid configurations in the SWIS is that they are all connected to Western Power's network at the distribution level. However, AEMO does not have visibility of these facilities under the existing regulatory framework set out in the Technical Rules and the WEM Rules. While the number of MicroGrids is small and dispersed across the SWIS, the impact on the power system is likely to be immaterial.

In aggregate, the effect of MicroGrids with DER on the power system will be determined by where they are located, including whether they are concentrated in any given area, and how quickly they are rolled out across the power network and hence the total installed MW capacity. The impact of MicroGrids is therefore determined by their ability to alter, and how quickly they can alter, system generation and system load profiles that ultimately drive frequency variations.

### 2.3.1 Embedded generation - NanoGrids

Embedded generation refers to dispersed installation of DER, for example, individual householders opting to install rooftop solar PV systems, and sometimes battery storage systems, and other 'smart' technologies that enable customers to offset and manage their own energy use. These customers might also sell excess electricity back to the retailer via a feed-in tariff or other arrangement. These arrangements could be considered 'nano' MicroGrids, or NanoGrids.

In Western Australia, the SWIS has a significant number of installed rooftop solar PV systems, compared with its average demand. AEMO estimates that of the one million residential customers, more than a quarter have rooftop solar PV systems installed, accounting for approximately 900MW of installed capacity.<sup>10</sup> This is likely to produce up to 30 per cent<sup>11</sup> of instantaneous generation from rooftop solar PV systems alone, notwithstanding that more instantaneous generation is provided by other renewable sources at the same time.

Variations in system load on cloudy days are noticeable, with changes of several hundred MW occurring over relatively short periods, whereas in previous years the load would have followed a more static and predictable trajectory. The impact on short term forecast accuracy over the past few years has also become much more pronounced, with traditional forecast models struggling to accommodate the volatility of energy generated behind the meter.

### 2.3.2 Fringe-of-grid solutions and stand-alone power systems

AEMO has chosen to address fringe-of-grid solutions and low voltage stand-alone power systems are addressed together as each is normally installed as a remedy for network reliability issues,

<sup>10</sup> AEMO estimates that of the 1,001,272 residential customers, 256,417 have rooftop solar PV systems installed. This equates to a total of 883MW of installed capacity on the South West Interconnected System.

<sup>11</sup> Actual generation of electricity by the indicated 900MW installed capacity varies based on solar angle, time of year and weather conditions.

usually at a remote location at the edge of the electricity network or within the electricity network. The difference between the two configurations is that fringe-of-grid solutions normally cater for a community of customers whereas a stand-alone power system has a sole customer. These 'remote' MicroGrids substantially reduce customers' reliance on the electricity network and are capable of operating (for some specified period) when completely islanded from the electricity network. They are, predominantly, a non-network solution to address a supply reliability problem.

In Western Australia, Western Power is implementing an initiative that will see Kalbarri powered by a small-scale MicroGrid that will also be connected to its network in the SWIS.<sup>12</sup> The town currently receives power via a 140km long rural feeder line from Geraldton. This feeder is exposed to weather events and interference, which can lead to supply reliability issues, that is, extended power outages.

The Kalbarri MicroGrid comprises a 4.5MWh battery to supply 5MW of peak capacity with at least 2MWh of energy storage to be accessible at any time for reliability back-up services. Renewable energy from residential rooftop solar and a local wind farm will provide additional supply. New renewable generation sources can be integrated in future.

In another example, Western Power has installed a 1MWh network (community-scale) battery storage systems on its network just outside of Perenjori as a back-up power supply.<sup>13</sup> It is anticipated that the battery will improve supply reliability to address faults on the main electricity network, thereby eliminating up to 80 per cent of outages. It is expected that rooftop solar PVs and battery storage will be included as part of the initiative as they become available.

### 2.3.3 Embedded networks

Embedded networks are more complex than fringe-of-grid solutions. In its 14 February 2018 transcript of evidence, the PUO commented that the main difference between embedded networks and stand-alone power systems is that embedded networks generally comprise multiple customers behind a single point at which Western Power or Horizon Power's network ends and the customer's distribution network begins. AEMO would suggest that a distinguishing characteristic of an embedded network is that this type of MicroGrid system is installed for a reason other than to guarantee reliability of supply, even though its practical operation may lessen reliance on the electricity network. The reason may be to reduce customers' electricity costs or provide other benefits (such as combined heat and power).

An embedded network may comprise a localised collection of household rooftop solar PV systems and other DER, such as a battery storage system. The embedded network may offer its customers the option of selling excess electricity generated by the embedded network back to the retailer and/or between customers.

A current Western Australian example is the joint project between Western Power and Curtin University to trial a solar-powered MicroGrid and battery storage system in White Gum Valley that will enable power sharing between neighbors.<sup>14</sup> This initiative includes a 300kWh battery storage system and 150kW of solar panels to be built within a new residential complex. It is expected the peer-to-peer sharing of electricity will provide around 70 per cent of the energy needs of trial participants.

<sup>12</sup> <https://westernpower.com.au/energy-solutions/projects-and-trials/kalbarri-microgrid>

<sup>13</sup> <https://westernpower.com.au/energy-solutions/projects-and-trials/perenjori-network-battery>

<sup>14</sup> <https://westernpower.com.au/energy-solutions/projects-and-trials/white-gum-valley-energy-sharing-trial>

## 3. Microgrids and the power system

Operation of the power system to deliver electricity to consumers is the outcome of a complex integrated system of independent systems, which must be highly coordinated. The power system can function well only when operated within certain physical parameters that adhere to particular engineering principles. Properly configured and managed, MicroGrids with DER can contribute to a secure and reliable power system.

### 3.1 The South West Interconnected System

To understand how MicroGrids with DER affect the operation of the power system, and therefore AEMO's ability to carry out its functions as the power system operator, clarification is required on what is meant by the 'power system', 'power system security' and 'power system reliability'.

The *Electricity Industry Act 2004*<sup>15</sup> defines the SWIS as the interconnected transmission and distribution systems, generating works and associated works located in the South West of the State and extending generally between Kalbarri, Albany and Kalgoorlie, and into which electricity is supplied by specified and prescribed electricity generation plants.

The Technical Rules, which are made under this legislation, define the power system as the electric power system constituted by the SWIS and its connected generation and loads, operated as an integrated system.<sup>16</sup> In everyday terms, this means the electricity network that is operated by Western Power (as the network operator) and assets connected to that network.

This network is the physical means by which energy (as traditionally generated by coal-fired generators and open cycle gas turbines, and more recently by utility-scale solar farms and windfarms) transport electricity to load (such as large energy users and small use consumers), most usually via the services of an energy retailer.

The power system works within a prescribed (frequency) operating standard and technical envelope. Power system security is defined as the ability of the SWIS to withstand sudden disturbances, including the failure of generation, transmission and distribution equipment, and secondary equipment, while maintaining frequency levels and continuing to operate within the technical envelope.

A related term is power system reliability, which means the ability of the SWIS to deliver energy to consumers within reliability standards while maintaining power system security and power system adequacy.<sup>17</sup>

Power system security and supply reliability are inextricably linked in power system operations. For example, a major generator or transmission line failure (a reliability issue) may cause system frequency to drop, triggering an emergency frequency control scheme (a technical service to restore system security), which may shed load to rebalance frequency.

<sup>15</sup> Section 3 of the *Electricity Industry Act 2004*.

<sup>16</sup> Attachment 1 – Glossary of the Technical Rules.

<sup>17</sup> Refer to the Wholesale Electricity Market Rules Glossary. Power System Adequacy is defined as the ability of the South West Interconnected System to supply all demand for electricity in the South West Interconnected System at the time, allowing for scheduled and unscheduled outages of generation, transmission and distribution equipment and secondary equipment.



## 3.2 The power system and the changing generation mix

AEMO's Power System Requirements report<sup>18</sup> outlines the services required to keep the power system secure and reliable and how they can be provided. This is a useful reference to understand some of the more technical terms that describe power system operations, such as voltage control and inertia.

In the past, many of the systems and processes used to manage power system security were available as a natural by-product of investments in traditional generation plants and ancillary services, such as:

- The inherent characteristics of synchronous generating plant (which provide inertia and droop).
- Network design requirements (which provided for redundancy and protection systems).
- Technical requirements for network connection and access.
- Procurement standards for ancillary services.
- Observance of network constraints in the energy dispatch process.
- Supplementary investments by the network operator and relevant actions by AEMO where security (and also reliability) has been identified as an issue.

As the generation mix changes to include more non-synchronous generation, such as inverter connected utility-scale renewable sources, it is becoming more challenging to maintain the security and reliability of the power system. In the NEM, AEMO has found it increasingly necessary to impose constraints on generation and to use its power to direct to maintain system security and a reliable operating state.

For example, in South Australia, the high proportion of non-synchronous generation means AEMO often intervenes to maintain a balance between synchronous and non-synchronous generation. Using its power to direct to meet the need for a level of conventional plant in these circumstances is necessary but undesirable. It generally leads to higher costs to customers through intervention pricing and the payment of compensation.

In Western Australia the impact of increased penetration of non-synchronous generation in the SWIS is expected to be felt in terms of lower levels of inertia, reduced system strength, and more rapid changes in frequency following single and multiple contingency events. These three interlinked issues combine to threaten power system security, particularly at times of low demand.

Displacement of synchronous generators by DER and other intermittent generators has led to (mid-day) decommitment of synchronous generators and recommitment of expensive fueled generators, such as gas turbines, to ramp up to meet (evening) peak load.

According to the WEM Market Data Dashboard, the record minimum demand experienced by the WEM was 1,178MW in 2008 (overnight). The SWIS has historically achieved its minimum demands overnight with low residential and commercial usage, however in recent years with the increasing levels of rooftop solar PV systems, this has changed to solar noon on sunny mild weekend days. While overnight minimum demand has grown since market start with increasing population and industrial load, on 29 October 2017, demand in the WEM fell to 1,304MW around midday. Lower levels are expected in the future. Given that rooftop solar PV systems are contributing to historically low levels of peak demand,<sup>19</sup> the power system security consequences of rooftop solar PV systems, and DER in general, must be properly understood and managed.

<sup>18</sup> This document has been written from a NEM context so some of the terms are different to those used in the WEM, however the underlying concepts remain the same. See [https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security\\_and\\_Reliability/Power-system-requirements.pdf](https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power-system-requirements.pdf)

<sup>19</sup> The lower peaks in 2017 and 2018 summers were directly driven by weather- no days above 38.5°C in 2018 while the peak day in 2017 only reached 37.7°C. AEMO has determined that saturation of rooftop solar PV would reduce the peak by about 8% and shift the peak to later in the day.

State government policies supportive of rooftop solar PV systems and attractive payback periods have contributed to a rapid uptake of rooftop solar PV systems. As outlined in section 1.3, AEMO expects continued growth in the installation of this type of embedded generation as the costs of rooftop solar PV systems decrease and electricity prices increase. This has important implications for AEMO as the power system operator for the SWIS and the market operator of the WEM.

AEMO has historically treated the rooftop solar PV capacity as negative load for forecasting purposes, but the SWIS is rapidly reaching a tipping point whereby this type of generation can no longer be treated in this way. It will be necessary to treat rooftop solar PV capacity as generation so that AEMO has sufficient visibility of rooftop solar PV capacity to effectively operate the power system and maintain system security.

It is expected that, after some critical level of non-synchronous generation is reached, power system security in the SWIS will be at risk if there are no changes to the current conventional systems and practices, and the WEM Rules and other regulatory instruments.

AEMO has been undertaking studies to assist its understanding of the potential power security issues that are likely to arise as the result of increasing levels of intermittent, non-synchronous generation, and to identify the level of non-synchronous generation capacity that can be accommodated in the SWIS before power system security issues arise. Unlike in South Australia, where AEMO regularly has to direct on synchronous generation, this point has not yet been reached but with increasing levels of DER and utility scale non-synchronous generation, these issues are inevitable.

### 3.3 Contribution of DER to power system and market objectives

The examples presented in Section 2.3 above highlight that the transitioning energy system is providing new opportunities to embrace emerging technologies and platforms to achieve the objectives of secure and reliable power, as well as long-term economic benefits to consumers in terms of reliability, affordability and sustainability.

If the right technical, regulatory and market frameworks are implemented to guide consumer activation via DER, then consumer needs can be effectively integrated with the technical requirements of the power system as it evolves to a low carbon electricity network.

Where sufficient visibility of DER can be achieved and practical coordination mechanisms implemented, then the capacity afforded by DER (either as part of MicroGrids or otherwise) can be leveraged to achieve both power system and market objectives.

The ways MicroGrids and DER can contribute at a power system level include:

- reducing energy losses by generating electricity at the usage point;
- improving power system resilience by offering a source of energy in the event of an emergency;
- improving power system security by providing fast responding storage capacity from battery storage systems which contribute to frequency response;
- introducing flexibility in the demand-supply balance by load shifting, capacity creation and demand management;
- adding diversity to the mix of generation for ancillary services (or otherwise reducing the need for, and supply of, ancillary services); and
- reducing the requirement for capital investment for network expansion and other generation capacity.

The resulting benefit to consumers is likely to be an overall reduction in costs to supply energy while enabling customer choice and the decarbonisation of the electricity network.



## 4. Operating and technical challenges of DER

The presence of DER do not in themselves create issues for maintaining power system security. Instead, DER presents new operating and technical challenges that need to be addressed in the context of managing power system security. These challenges can be mitigated by affording AEMO visibility and coordination of DER, under the regulatory framework, for DER assets connected to the network.

### 4.1 Operating challenge – lack of visibility and coordination

AEMO would normally have remote visibility of most transmission connected equipment in the SWIS, including those parts of the SWIS that can be disconnected and run independently as their own ‘islands’. One example of this is the Eastern Goldfields.

AEMO’s visibility does not typically extend to equipment outside of the high voltage transmission network, that is, the medium voltage distribution feeder equipment and to mains level low voltage equipment. In some cases, Western Power has remote visibility of some of this equipment in their Distribution Management System, where the equipment is telemetered. This typically includes larger scale installations. However, at present, even Western Power would not typically have remote visibility of mains level low-voltage equipment such as household embedded generation, for example, rooftop solar PV systems.

An added complexity is that until very recently, rooftop solar PVs systems were not required to be manufactured to a specified standard in regard to their response to power system frequency disturbances.<sup>20</sup>

Given there is no general authority under the existing regulatory instruments for the power system operator or the network operator to coordinate rooftop solar PV system output, the management of frequency disturbances becomes more difficult with increased levels of rooftop solar PV system penetration and the commensurate increased levels of volatility of energy generated behind the meter.

A significant issue will arise when rooftop solar PV system output reaches a level that may require AEMO to constrain output to keep the system in a secure operating state for normal operation and in responding to contingency, but does not have sufficient visibility of DER or the authority to coordinate DER to do so.

<sup>20</sup> AS4777.2-2015 applies to all rooftop solar PV systems installed as of 9 October 2016, requiring that the system:

- is capable of zero-export to maintain the frequency (ie. avoid over-frequency); and
- is capable of remaining connected to the network for frequencies in the range of 47 Hz – 52 Hz.

The earlier version (AS4777-2005) did not require a standardised response to system frequency. Consequently inverters were manufactured and sold with a broad range of default settings for on-board under-frequency protection.

## 4.2 Technical challenges

There are several technical challenges that need to be addressed for the effective integration of MicroGrids with DER.

### 4.2.1 Protection implications

Power systems, which automatically operate to isolated faulted equipment on the power system, were traditionally designed to accommodate power flow from generators to consumers. Protection systems have been designed and installed accordingly. With the advent of DER, the SWIS is increasingly experiencing multi-directional power flows due to consumers, which have traditionally been treated as load, becoming generators from time-to-time. Existing protection systems will need to be enhanced to accommodate the new reality of network usage.

Additionally, DER may reduce the fault level and short circuit ratio, which are fundamental requirements for the protection system to operate correctly.

### 4.2.2 Voltage control

The more heavily populated a distribution feeder becomes with embedded generation, the more voltage rise there is on that feeder. This in turn requires active measures to be taken 'up-stream' to help maintain secure voltage levels. It can be difficult to maintain the voltage at the primary distribution substation at a point that is both secure for all connected equipment, and within normal voltage operating limits for all feeders.

### 4.2.3 Load smoothness and predictability

The system load is measured by how much energy is required to be dispatched to maintain system frequency. When a large amount of intermittent DER actively off-sets the demand or exporting energy back into the grid, this looks like a 'reduction' in the system load. The intermittent nature of this 'reduction' creates large variability and swings in the measured system load, which are inherently difficult to forecast or predict. For example rapidly changing cloud cover will significantly impact the output of rooftop solar PV systems.

### 4.2.4 Response to disturbances

In its operational planning, AEMO performs load modelling to understand how load will behave in response to disturbances in the power system. This has traditionally been static. However, the increased penetration of DER means that the response of the demand side to disturbances is more dynamic, and dependent on the electronic settings of the individual DER devices. A lack of visibility of this behaviour can have implications in the management of contingency events.

### 4.2.5 System frequency

At present 'islandable' MicroGrids with DER are small and few in number and the impact on system frequency is minor. As the number and scale of these MicroGrids grow, unscheduled or badly timed disconnections (or reconnections) of such MicroGrids from the SWIS, where they occur simultaneously, can potentially cause large deviations in the system frequency or voltage. This can lead to balancing generators receiving instructions that require them to constantly adjust their generation (and/or adjust for increased levels of ancillary services, leading to additional electricity market costs).

Even if these adjustments are not large enough collectively to cause a frequency disturbance, numerous disconnection/reconnection events will also impact the profile and predictability of the load (similar to the above example).

A critical issue arising from uncoordinated DER growth (particularly rooftop solar PV systems), is that at some point, the total output from rooftop solar PV systems will be greater than the demand on the system (ie. on low demand sunny days). This excess generation can result in an inability to

dispatch sufficient frequency control ancillary services to manage system frequency effectively. In a situation of high rooftop solar PV output, should invertors 'trip' *en masse* in an uncontrolled manner, with insufficient frequency control ancillary services online and available this can result in subsequent under frequency load shedding.

The worst case outcome of such a scenario is a total system blackout. This point may not be far away, considering the projected increases in embedded generation. It is possible that alternative ancillary service arrangements may be required to deal with this problem. With more utility-scale synchronous generators expected to exit the market, this work needs to proceed with some urgency.

#### 4.2.6 Under-frequency load shedding

When severe contingencies occur resulting in multiple concurrent generator failures, the frequency depression can become so severe that automated load shedding is required to prevent the system from collapsing. Under-frequency load shedding schemes are implemented based on static settings using fairly broad assumptions regarding the load distribution and profile on the distribution network.

With the growth in MicroGrids with DER, some distribution feeders can become net exporters at times. If the distribution feeder is exporting during an under-frequency load shedding event and the feeder is disconnected, instead of aiding the restoration of power system, disconnection can have the opposite effect and result in the system frequency decaying even further. If disconnection occurs over too many feeders at the same time, the power system can potentially collapse.

### 4.3 How are MicroGrids and DER managed now?

With the exception of NanoGrids, AEMO coordinates with Western Power to manage MicroGrids with DER. However, this coordination occurs on an informal basis. This may require Western Power to notify AEMO where an issue requires coordination and AEMO does not have direct visibility, for example, in regard to a distribution voltage problem.

The growth rate of MicroGrids with DER in some locations will out-pace the rate at which control measures such as network augmentation can be implemented. Broader control measures will therefore be required upstream to resolve a localised issue on the power system. One example might include constraining the generation output of a market participant to change the level of reactive power absorption on its generator in order to resolve a distribution voltage issue.

While improved visibility for AEMO and Western Power is fundamental to managing the challenges posed by MicroGrids with DER, there are specific technical challenges (such as protection implications and distribution voltages) that the network operator is the best placed to resolve as part of a longer-term solution.

In terms of NanoGrids, AEMO's ability to forecast the generation and load profiles associated with DER such as rooftop solar PV systems is limited, and under the current regulatory regime, AEMO does not have real-time coordination of DER including rooftop solar PV systems. With the right policy settings, technical requirements and market-driven investment signals, there is potential for NanoGrids and other forms of DER to be effectively and actively managed and coordinated by AEMO and Western Power via their aggregation into a larger MicroGrid configuration.

### 4.4 MicroGrids with DER can be used to manage power system security

Properly managed, MicroGrids with DER could become active participants in the operation of power system to maintain power system security. The ways in which DER can participate include:

- Demand management, which already plays a role in assisting in the supply-demand balance and restoring the power system following disturbances or in reducing peak demand.

- Real-time demand (or battery storage systems) could be used to follow variable supply, disrupting the traditional model of supply following load. Real-time demand also would benefit AEMO in providing flexible demand that could respond quickly if needed.
- With the appropriate coordination signals and systems, DER could potentially assist in managing voltage levels.<sup>21</sup>
- If appropriately aggregated, some DER could provide ancillary services, such as frequency control, which is currently provided by conventional generation.
- Assisting in emergency situations via active control, for example, the curtailment of rooftop solar PV systems during severe weather events.
- MicroGrids with DER, particularly at the fringe of the network, can reduce power losses across the transmission and distribution networks.

With the correct connectivity technology (ie. smart meters), and relevant changes to regulatory and technical requirements, MicroGrids with DER can be used to provide ancillary services for power system security (including load following, spinning reserve, load rejection and voltage support) and services for energy trading and demand management. This improves the effectiveness of the electricity markets by reducing variability, inaccuracy of forecasts and introducing competition.

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<sup>21</sup> Via power-factor / MVAR control.

## 5. MicroGrids with DER and the Wholesale Electricity Market

The power system is likely to shift to an operational model characterised by flexible demand and more variable supply. Properly incentivised, MicroGrids can be used in conjunction with smart metering and other innovative energy trading approaches to deliver both power system security and improved outcomes and choice for consumers. MicroGrids can therefore help meet the challenges posed by DER by enabling the visibility and coordination required to materialise the potential benefits that DER can provide to the power system and energy market.

In liberalised electricity markets, wholesale power exchanges (including the WEM and the NEM) seek to coordinate the actions of numerous participants in a manner that delivers electricity at a competitive price, while maintaining the reliability and security of the power system. These exchanges frequently transact energy and additional reliability and security products, which may include capacity (such as the WEM's Reserve Capacity Mechanism) or ancillary services to support system frequency or voltage.

Wholesale power exchanges are most effective when they provide transparent and reliable price signals to suppliers and customers, and provide opportunities and incentives for parties to actively respond to those price signals. Historically, these objectives have been achieved through a central dispatch process that forecasts the demand for electricity (and ancillary services) and optimises the various suppliers to meet that demand.

The rapid growth of variable renewable generation and DER is challenging this model. The proportion of electricity generation that is optimised through the central dispatch process has decreased and the reliability of forward price signals has reduced.

The demand for dispatchable generation through the central dispatch process is becoming increasingly variable, due to displacement by utility-scale renewable generation with lower operating costs, and by variable rooftop solar PV on the customer side. If left unchecked, this trend would likely lead to greater reliance on ancillary services to maintain the power system security and reliability and reduce investment in new capacity, both of which would result in increased costs for consumers.

The WEM Rules prescribes the 'types' of ancillary services to be procured, the standard to which they are procured, and the circumstances under which they are dispatched. It may not be practicable or cost-effective in the longer term to continue procuring and deploying the same types of ancillary services as MicroGrids and DER become increasing popular among consumers in the SWIS.

MicroGrid configurations such as embedded networks can provide a means of aggregating and coordinating DER and smaller MicroGrid arrangements such as NanoGrids. This can potentially boost consumer participation in wholesale exchange, improving forecasting and the reliability of price signals.

## 6. Regulatory considerations

AEMO is supportive of new technologies in providing choice for energy consumers and energy polices geared towards making electricity more secure, reliable and affordable while lowering emissions. However, AEMO's ability to implement innovative solutions and provide a platform that allows others to innovate is limited by the functions, authorisations and protections given to it under the current regulatory framework.

### 6.1 The WEM Rules

Under the WEM Rules as currently drafted, the Minister for Energy may issue a statement of policy principles to the Rule Change Panel with respect to the development of the market,<sup>22</sup> which the panel must have regard to when making amending rules<sup>23</sup>. Any statement of policy principles therefore only comes into play when the Rule Change Panel is considering whether to amend the WEM Rules.

In Western Australia, there is no regulatory mechanism to translate the Minister's policy objective for the electricity industry into a requirement for AEMO to change market or power system arrangements to realise the policy objective. AEMO does not have the authority or statutory protections to do preparatory work in support of reforms, and ostensibly, to address emerging issues that impact business as usual where material changes are required to market and power system arrangements.

The WEM Rules place limits on AEMO's level of involvement by giving AEMO:

- functions in respect of the WEM, which include operating and administering the various aspects of the WEM;<sup>24</sup> and
- the function of ensuring that the SWIS operates in a secure and reliable manner.<sup>25</sup>

AEMO's functions with regard to the WEM and the SWIS are narrowly defined and do not provide sufficient scope for AEMO to prepare for, assist with or take actions to implement, material changes to the design and operation of the WEM and the power system in the SWIS.

AEMO's function of ensuring that the SWIS operates in a secure and reliable manner does not fully encompass power system planning. In the NEM, AEMO is developing its Integrated System Plan, in fulfilment of recommendation 5.1 of the *Independent Review into the Future Security of the National Electricity Market* (Finkel Report) published mid-2017.<sup>26</sup>

Recommendation 5.1 requires AEMO, with the support of transmission network service providers and stakeholders, to develop a fully integrated strategic plan for facilitating the efficient development and connection of renewable energy zones across the NEM. AEMO's Integrated System Plan is scheduled for release in mid-2018, with DER a key component in its analysis.

<sup>22</sup> Clause 2.5.2 of the Wholesale Electricity Market Rules.

<sup>23</sup> Clause 2.5.3 of the Wholesale Electricity Market Rules.

<sup>24</sup> Clause 2.1A of the Wholesale Electricity Market Rules.

<sup>25</sup> Clause 2.2 of the Wholesale Electricity Market Rules.

<sup>26</sup> Finkel, Alan; Chloe Munro, Terry Effeneey and Mary O'Kane (2017), *Independent Review into the Future Security of the National Electricity Market: Blueprint for the Future*, Council of Australian Governments, June. See <https://www.energy.gov.au/publications/independent-review-future-security-national-electricity-market-blueprint-future>

A suitably crafted system planning function would facilitate prudent investment in the SWIS, and provides greater choice for electricity consumers through the integration of renewable energy and innovative technologies. AEMO is already required to develop, in consultation with industry participants, and publish, an annual WA ESOO for the WEM and an annual Gas Statement of Opportunities for Western Australia. The WA ESOO for the WEM contains forecast demand scenarios and planned investment in generation and network investment over a (minimum) ten-year horizon.

Under a system planning function, AEMO might be required to develop options to accommodate increasing levels of renewable generation and rooftop PV systems. For example, work with relevant stakeholders to investigate and implement strategies for ‘renewable zones’, to design specialised network and non-network services for system security and supply reliability, or to determine how (and what type of) ancillary services will best accommodate new technologies while maintaining system security. A more extensive planning function might create obligations on relevant bodies to take steps to implement any approved options.

## 6.2 AEMO’s statutory protections

AEMO is a ‘market governance participant’ and a ‘system management participant’ as its functions are conferred under the WEM Rules in accordance with the *Electricity Industry Act 2004*.<sup>27</sup> Under this legislation, AEMO and its officers and employees are protected (do not incur any civil monetary liability) for a non-negligent act or omission done or made in good faith in the performance or purported performance of a function under the WEM Regulations or Rules (broad indemnity).

If the act or omission is done or made in good faith but negligent, then the broad immunity does not apply and a liability cap applies instead (capped immunity). The capped immunity only applies with respect to AEMO’s market operation functions. In the case of AEMO’s system operation functions, if the act or omission is negligent, then (regardless of whether or not it is made in good faith) the capped immunity does not apply.<sup>28</sup>

The corollary of this prescription is that where AEMO or its officers or employees perform duties outside of a conferred function, there is no statutory protection in respect of an act or omission – regardless of whether or not the act or omission was done or made in good faith or negligent.

## 6.3 The Technical Rules

The Technical Rules set-out the responsibilities, authorities and obligations on ‘System Management’ (AEMO), the network operator (Western Power), network users and the Economic Regulation Authority as the rule change authority in regard to the day to-day operation of the SWIS.

More specifically, the Technical Rules detail the actions that System Management may take as the power system operator, and specifies the points of day-to-day operational interaction between System Management and the network operator in regard to exemptions, power system performance, technical requirements of user facilities for connection, inspection, testing, commissioning, disconnection / reconnection and power system security operation and coordination.

With no amendments made to the Technical Rules, the transfer of the System Management function from Western Power to AEMO resulted in a situation where the existing functional boundaries underpinning day-to-day interaction between Western Power and AEMO do not sufficiently reflect or support the current reality of the roles being performed by AEMO and Western Power.

<sup>27</sup> Sections 121(2)(b) and 126(1) of the *Electricity Industry Act 2004*.

<sup>28</sup> Sections 126(2), (3) and (4) of the *Electricity Industry Act 2004*.



To mitigate the risk to responsible parties in any case, and in relation to the increasing presence of DER, the functional boundaries will need to be revised and formalised.

Even when the Technical Rules are amended to address this misalignment AEMO (as the power system operator) will remain subject to, and be required to comply with, key accountabilities and obligations given by an instrument that places requirements on Western Power as a network operator. There is no scope under the Technical Rules for any party to undertake power system (as opposed to network) planning or for a party other than Western Power to propose a change to the network planning criteria. An opportunity exists to reform the change process for the Technical Rules, which may include harmonising the existing processes with the process that applies to amending the WEM Rules, and to enable a greater range of stakeholders to propose changes.

## 6.4 The Metering Code

There are opportunities to improve the Electricity Industry (Metering) Code 2012 (Metering Code) to accommodate MicroGrids and DER so that residential customers can trade their energy between themselves (ie. peer-to-peer), either as part of embedded network or outside of an embedded network.

### 6.4.1 Necessary changes to accommodate DER

The Metering Code requires a single connection/revenue meter for every connection point. This is the point at which net consumption is measured.

At present, the Metering Code requires 'net' metering, meaning that revenue meters must measure and record 'net' electricity production and consumption.<sup>29</sup> If a residential customer is generating electricity and at the same time consuming electricity the network, the meter will only record the net (difference) of the two activities. Therefore, electricity generated by a rooftop solar PV system is treated as net of the load consumed by the residential customer.

Amendments to the Metering Code to enable the feed-in tariff has allowed the residential customer to sell its excess generation (net electricity) back to the energy retailer. However, further amendments will be required to this instrument to allow the residential customer to sell its excess generation to another residential customer, as in 'peer-to-peer' trading.

### 6.4.2 Further necessary changes to accommodate embedded networks

At present, activity occurring past the single connection/revenue meter is the responsibility of the customer and is not covered by the Metering Code.<sup>30</sup> Most apartment buildings, shopping centres and airports have private sub-meters. These types of customers are normally metered at their connection point(s) which is their point of connection to the network.

Should these customers choose to build embedded generation and trade their electricity outside their embedded network, then there is no means of facilitating revenue metering in this situation and no algorithm to enable electricity market trading by the customers within the embedded network.

Amendment to the Metering Code will be required to allow for new meter data agents who can perform special meter data services (such as multiple site data aggregation).

<sup>29</sup> Clause 3.3C of the Metering Code. Metering of bi-directional electricity flows An accumulation meter or an interval meter that separately measures and records bidirectional electricity flows at the metering point must record:

- (a) the net electricity production transferred into the network that exceeds electricity consumption; and
- (b) the net electricity consumption transferred out of the network that exceeds electricity production.

<sup>30</sup> Private embedded networks and private sub-meters are not covered by the Metering Code.



## 6.5 Other considerations - virtual power plants

The term ‘virtual power plant’ refers to an arrangement where renewable energy generation, battery storage systems and load control systems are coordinated via intelligent (web-based) technology over a geographically dispersed area. A virtual power plant acts as an intermediary between DER and the WEM to trade energy or provide ancillary services on behalf of DER owners and behaves as a conventional dispatchable power plant.

The arrangement has some similarities with embedded networks<sup>31</sup> in that both arrangements seek to aggregate DER to provide services to the power system or to mitigate electricity costs. However, the dispersed nature of DER within a virtual power plant will require specific consideration during the development of regulatory, technical and commercial policy to ensure there is sufficient visibility and coordination of DER. A higher level of coordination between AEMO and Western Power will be required so that aggregated output (or changes in output if providing services) at the wholesale level does not adversely affect operations at the distribution level.

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<sup>31</sup> Although an embedded network is a localised arrangement.

## 7. Successful integration of MicroGrids with Distributed Energy Resources

The successful integration of MicroGrids with DER into the WEM will require broad but complementary programs of work across the industry. Changes will be necessary to the regulatory framework and existing technical requirements, authorisations and obligations. The state government's lead role on policy and its on-going regulatory involvement, as well as innovation in retail markets, will be pivotal to realising the potential gains to be made from MicroGrids and DER for power system security and consumer choice.

### 7.1 The regulatory framework

Communication and collaboration with industry will be as important to the successful integration of MicroGrids with DER as facilitating the necessary infrastructure to enable the solutions. As new installations are occurring daily and the retrofitting of new technical capabilities can be a costly exercise, the timing of activities to support integration is critical. Successful integration will also necessitate substantial amendments to the regulatory framework to address the system and market consequences of increased penetration of utility-scale renewable generation as well as MicroGrids and the DER within.

At the same time, the PUO's current reform program for the WEM and the power system to implement a constrained network access model, including security-constrained economic dispatch will require changes to the WEM Rules, the Technical Rules and other regulatory instruments. It is expected the changes will set-out authorisations, requirements and processes for generator performance standards, approval for generator connection and access, generator performance monitoring and compliance, and electricity network code and performance standards.

So that the new arrangements have sufficient longevity, AEMO is working with the PUO to redesign the regulatory and technical aspects of power system operation to enable the participation of new technologies and new ways in which consumers are seeking to use Western Power's network.

In this context, amendments to the existing regulatory framework and instruments might aim to:

- Provide for sufficient visibility, and potentially coordination, of all generation facilities and technologies connected to the SWIS where there are likely to be power system security implications. This may include, for example, a register of DER installed in the SWIS.
- Remedy the existing misalignment between the functions of, and requirements on, AEMO as the power system operator and Western Power as the network operator.

- Implement a new change approval process for the Technical Rules, or otherwise harmonise the existing change approval process with that of the WEM Rules, to enable AEMO (and potentially other stakeholders) to propose amendments.
- Ensure that AEMO (as the power system operator), Western Power (as the network operator) and other entities (such as the Economic Regulation Authority) have sufficient jurisdiction to effectively and efficiently perform their functions and responsibilities.
- Provide for a new power system planning function to ensure risks to power system security can be properly anticipated and managed.

## 7.2 The Wholesale Electricity Market

To enable the active participation of MicroGrids and DER in the WEM, particularly as a vehicle to enable aggregation, modifications will be required to many aspects of the WEM design. These modifications will likely need to include:

- a review of the reliability and security standards for the SWIS;
- clearly defined ancillary services that are aligned with the reliability and security standards for power system operation;
- appropriate procurement mechanisms for those ancillary services, having regard to the potential for competition to lower costs for consumers;
- efficient allocation of ancillary service costs to promote investment and behaviour that reduces total system cost; and
- market registration classes and requirements (e.g. data provision and communication) to enable participation of MicroGrids in the WEM.

Some of this work has already commenced in the context of the constrained network access reforms that are being led by the PUO.

## 7.3 Metering

Should customers be afforded greater choice under the existing regulatory regime through the trading of their energy, either directly or via an aggregator, then the Metering Code will need to be amended.

## 7.4 International experience and DER

While the SWIS and the WEM are unique in a number of aspects, the energy transformation that is being experienced with regard to the penetration of DER is not too dissimilar to that which is occurring in electricity systems around the world. How specific aspects of DER are being managed and/or integrated overseas can help inform how DER and MicroGrids can be successfully integrated in Western Australia.

One approach to managing the integration of DER in some international jurisdictions is to mitigate the emerging technical challenges while seeking to maximising consumer value. Other international jurisdictions have taken a different strategic approach that includes focussing on incentivising the uptake of DER due to low penetration levels.<sup>32</sup> A few high-level examples are provided below.

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<sup>32</sup> See for example 51<sup>st</sup> State Perspectives, Distributed energy resources integration: Policy, technical, and regulatory perspectives from New York and California. Available at: <https://sepapower.org/resource/51st-state-perspectives-distributed-energy-resources-integration-policy-technical-regulatory-perspectives-new-york-california>

California and Hawaii are the most similar to Australia in terms of their experience with DER (mainly in the form of rooftop solar PV systems) as both jurisdictions have high levels of DER penetration and are already facing technical challenges. California Public Utilities Commission's integrated Distributed Energy Resources Program<sup>33</sup> acknowledges that successful integration will rely on collaboration with industry and effective communication, as well as the need to facilitate the necessary infrastructure to enable practical solutions. The strategy is time critical as new installations are occurring daily and retrofitting new technical capabilities can be costly. Adding to the urgency is the likely length of the implementation time of some solutions.

In another example, Hawaii has enabled dynamic feed-in management capabilities to avoid the need for blanket 'caps' on rooftop solar PV installation, or restrictions on grid feed-in.

With little DER penetration, New York has determined a different objective for DER as part of its comprehensive Reforming the Energy Vision, at least in the short to medium term. New York's strategy centres on market incentives to encourage, among other things, the uptake of DER to meet its Clean Energy Standard. This standard will ensure that 50 per cent of New York's energy will come from renewable sources by 2030.<sup>34</sup>

There are also lessons to be learned from Germany in terms of the cost of retrofitting rooftop solar PV inverters and how it, and other European nations, manage solar eclipse through visibility and planning. Approximately 400,000 rooftop solar PV inverters were updated as all had been configured to disconnect from the network at a frequency of 50.2 Hz. If this number were to disconnect all at once, a large contingency event would occur, and potentially forcing a major power system situation. The cost to retrofit was estimated to be around 175 million euros plus the administrative costs for inverter manufacturers and the Distribution Network Service Providers.

## 7.5 The retail market

Owners of DER will need to be appropriately incentivized so that the benefit of DER for all consumers can be maximized. New technology is enabling customers to manually or automatically control their DER and energy usage, and therefore their overall import from and export to the network, while maintaining their lifestyles.

The SWIS, as a network of reasonable scale, with a single network owner and a single retailer of small consumers, is uniquely positioned to enable benefits from innovative retail arrangements. The remainder of Western Australia is similarly well-placed, with Horizon Power being the vertically-integrated electricity utility. AEMO notes that Horizon Power has already undertaken significant work in this area.

Historically, different retail energy products have been employed in Western Australia and other jurisdictions to enable customers to reduce their bills, thereby reducing overall system costs. Retail products such as extreme peak demand pricing (agreement in advance for customers to reduce demand on request) and fixed pricing (set monthly fee for a defined service with cap to service levels or higher costs for above agreed usage - similar to internet pricing) have been implemented in other Australian jurisdictions with differing levels of success.

MicroGrids and DER, however, can take this innovation to the next level in providing an enhanced platform that is supportive of other technologies, such as communications to the home and meters that can record usage at a granular level.

AEMO welcomes the Economics and Industry Standing Committee's inquiry of the regulatory, technical and market frameworks relating to MicroGrids and related technologies. AEMO looks forward to further discussions with the Committee and to working with the PUO, network operators, aggregators, retailers and other key stakeholders to explore the opportunities afforded by MicroGrids and DER for the benefit of Western Australian communities.

<sup>33</sup> See <http://www.cpuc.ca.gov/General.aspx?id=10710>

<sup>34</sup> See <https://rev.ny.gov>