DER Technology Integration

Functional Framework

6 July 2020

GridWise ENERGY SOLUTIONS

farrierswier

Disclaimer

This report has been prepared by Farrier Swier Consulting Pty Ltd (farrierswier) and GridWise Energy Solutions Pty Ltd for the sole use of the Australian Renewable Energy Agency (the "client"). This report is supplied in good faith and reflects the knowledge, expertise and experience of the consultants involved. The report and findings are subject to various assumptions and limitations referred to within the report, and supporting papers. Any reliance placed by a recipient of the report upon its calculations and projections is a matter for the recipient's own commercial judgement. Farrier Swier Consulting Pty Ltd and GridWise Energy Solutions Pty Ltd accept no responsibility whatsoever for any loss occasioned by any person acting or refraining from action as a result of reliance on the report.

Contents

LIST OF FIGURES

Glossary and abbreviations

Term	Definition
ADMS	Advanced Distribution Management System
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AESCSF	Australian Energy Sector Cyber Security Framework
API	Application Programming Interface
ARENA	Australian Renewable Energy Agency
AS/NZS	Joint standard developed by Standards Australia and Standards New Zealand
DEIP	Distributed Energy Integration Program: a collaboration of government agencies, market authorities, industry and consumer associations aimed at maximising the value of customers' DER for all energy users
DER	Distributed Energy Resources: non-registered resources connected to the distribution system that generate electricity or manage electricity demand
DERMS	Distributed Energy Resources Management System
DMO	Distribution Market Operator
DNSP	Distribution Network Service Provider
DSO	Distribution System Operator
EMS	Energy Management System
ESB	Energy Security Board
FCAS	Frequency control ancillary services
Functional areas	The key capabilities required for effective DER technology integration
GIS	Geographic Information System
Hosting capacity	The amount of DER that can be accommodated within a DNSP's network, or the relevant part of the network, without adversely affecting security, reliability or power quality
Integration	In simple terms, integration is the process of bringing together and uniting separate things into a comprehensive and cohesive whole. In the context of this paper, "integration" of DER technology covers the actions needed so that DER devices, the services DER can provide and DER-related systems and data become a cohesive part of the broader electricity system and energy markets

Term	Definition
Integration objectives	The objective of DER technology integration is to enable DER to be utilised efficiently to maximise the benefits for all consumers regardless of whether they have DER. The draft functional framework breaks this objective down into the following three integration objectives: • Supporting system security and reliability • Supporting network operation, reliability and power quality • Improving access to DER value streams
Integration topics	The key areas of DER technology integration
LV	Low voltage
MW	Megawatt
NEM	The National Electricity Market, which covers New South Wales, Queensland, Victoria, South Australia, the ACT and Tasmania
NEMDE	NEM Dispatch Engine: the software developed and used by AEMO for the NEM's central dispatch process
NER	National Electricity Rules
NSP	Network Service Provider (either a Distribution Network Service Provider or a Transmission Network Service Provider)
Operating envelope	The technical limits DER must operate within to maintain the security, reliability and power quality of the distribution network and broader electricity system. Operating envelope relates to the local distribution network in this context.
PFC	Primary Frequency Control
RERT	AEMO's Reliability and Emergency Reserve Trader function
SCADA	Supervisory Control and Data Acquisition System
SRAS	System restart ancillary services
TNSP	Transmission Network Service Provider
UFLS	Under frequency load shedding
VPP	Virtual Power Plant: a collection of aggregated DER devices working in a coordinated manner to generate or consume energy or provide other services
V2G	Vehicle to grid
WEM	Wholesale Electricity Market for the South West Interconnected System of Western Australia

1. What this project is seeking to do

1.1 WHAT IS THE PROJECT PURPOSE AND OUTPUT?

The Australian Renewable Energy Agency (ARENA) is working with farrierswier and GridWise Energy Solutions to develop a State of Distributed Energy Resources (DER) Technology Integration Report. This project will create a functional framework for DER technology integration, that will be used to conduct a maturity assessment. It will then prepare a baseline report to better understand the contributions made towards DER technology integration by current and recent ARENA and non-ARENA projects, programs and trials. This technical integration focus will recognise but exclude the analysis of broader market, grid and customer regulation projects already being considered by other parties.

The functional framework and maturity assessment has been designed for future application to track progress towards effective DER integration across Australia.

1.2 WHY IS THIS PROJECT NEEDED?

It is widely recognised that there are complex challenges in achieving a customer-focussed transformation of Australia's energy system. Yet transformation is needed so new technologies can benefit all consumers by enabling access to new services, reducing energy costs, improving system security and reliability, and facilitating a lower-emissions energy system. DER can play a key role in supporting these outcomes, particularly if the necessary technology and data is available so that DER can be effectively integrated into the broader electricity system and energy markets.

Many parties are currently working on addressing aspects of these transformational challenges. However, recent engagement has informed ARENA that many stakeholders – including industry, consumer groups and policy makers – struggle to understand the breadth of the current work underway on DER issues and the nature of ARENA's and others' more complex DER projects (ie what they are seeking to achieve, their method and approach, and how they relate to each other and other work underway by government agencies, market authorities, industry and consumer associations).

The State of DER Technology Integration Report will aim to synthesise that existing work and explain how it fits together in a manner that is accessible for people wanting an overarching view of the current state of DER technology integration, including both technical and non-technical stakeholders.

1.3 WHAT IS THE SCOPE OF THIS PROJECT?

Technology

The scope of this project is limited to *technology* issues related to DER integration. It includes technology related to DER devices themselves as well as the systems of parties that need to interact with DER devices (eg the Australian Energy Market Operator—AEMO, network businesses, aggregators and other energy service providers) and the communications systems and protocols required to facilitate that interaction. It also includes the data necessary to enable effective operation of DER and its integration into the broader energy system and market.

Standards related to DER technology and data are an important part of this project, with a range of international and Australian standards impacting on several key aspects of DER technology integration, particularly device capabilities and interoperability. The functional areas are therefore informed by current or potential future standards requirements. Projects related to changes to standards will also be included in the set of projects covered by the report. The governance of the standard-setting process and issues related to compliance with standards are extremely important to effective DER integration, but are not within the scope of this project and are instead currently being considered by the Energy Security Board (ESB).

The project does not encompass issues related to broader consumer, market design or regulatory issues related to DER. The scope is: *How can it work, what is needed for it to physically work, and how far advanced is the technology to achieve this?* It is not broader regulatory and policy questions like: *Who should do it and who pays?* Where the assessment identifies that a technology is itself mature but not yet enabled by either policy, market or regulatory frameworks, this will be noted.

Integration

The focus is on *integration* of DER technology into the broader energy system and market. In simple terms, integration is the process of bringing together and uniting separate things into a comprehensive and cohesive whole. In this context, DER technology integration covers the actions needed so that DER devices, the services DER can provide and DER-related systems and data become a cohesive part of the broader electricity system and energy markets.

The functional areas and projects covered in the project will focus on how DER can be integrated into the electricity system and electricity markets rather than issues solely related to specific DER technologies, eg projects related to improving the efficiency of solar PV or battery systems are not included.

1.3.1 How does this project complement other DER work?

The objective of DER technology integration is to enable DER to be utilised efficiently to maximise the benefits for all consumers regardless of whether they have DER. This objective is drawn from objectives for DER integration adopted by the Distributed Energy Integration Program (DEIP), the ESB and the Australian Energy Market Commission (AEMC).

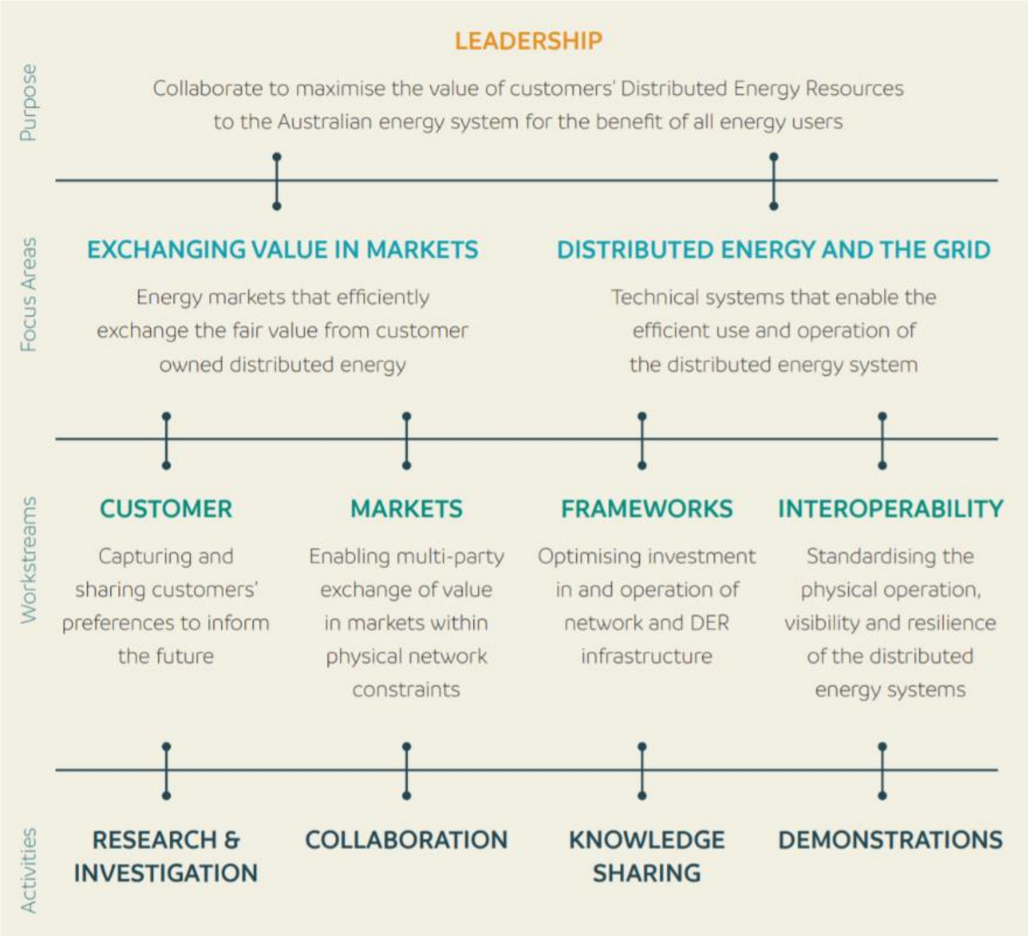
The DER technology integration scope will provide a physical enabler (through technology, systems and data) of these objectives. However, this physical enablement is by no means the only action required to deliver DER integration and unlock the full benefits of DER for consumers.

Other important and complementary work packages are looking at the broader customer, market, and frameworks areas of DER integration, including (among other things) the social and market research that is needed to support the uptake of DER technologies while ensuring beneficial outcomes for all customers. Together, these work packages will determine how and to what extent the social outcomes of DER such as affordability, equity and choice are realised.

Many of these work packages are being advanced through the DEIP. DEIP is a collaboration of government agencies, market authorities, industry and consumer associations aimed at maximising the value of DER for all energy users. DEIP's various elements are illustrated in Figure 1.1.

This distinction means it is important to define up front what is meant by DER technology integration, and the resulting scope for this project. Section 1.3 above does this for technology and integration, and DER is defined for the purpose of this project in section 2.1 below.

Figure 1.1: DEIP framework



Source: Distributed energy integration program overview | DEIP at a glance, February 2019

1.4 HOW WILL INDUSTRY STAKEHOLDERS BE ENGAGED?

The work comprises four key tasks, that will involve:

1. Completing an initial process of technology integration issue discovery, developing and consulting on a draft function framework, and publishing the final function framework that has been refined for stakeholder feedback—*the purpose of this paper*

2. Preparing summaries of current and recent projects agreed with ARENA to help develop an understanding of these DER projects, what they seek to achieve, their method and approach, and how they relate to each other, including through liaison with the project leads

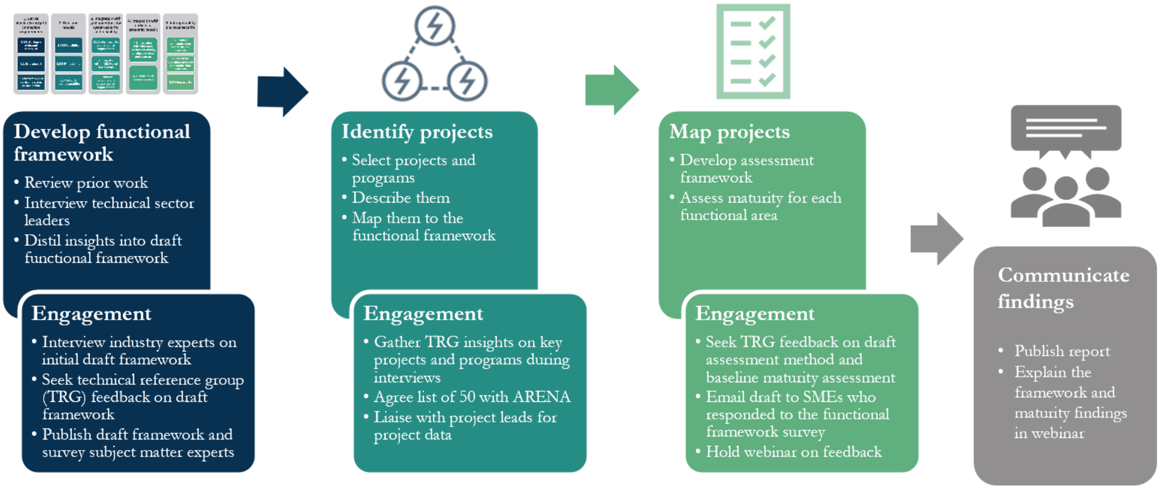
3. Establishing and applying a maturity assessment method for assessing how the projects collectively contribute to the maturity of each functional area in the integration framework, and then consulting on this

4. Collating all the above in a final project report and associated communication materials.

The work is being refined through stakeholder engagement

The State of DER Technology Integration Report is being developed through a staged consultative process with a broad range of stakeholders, as illustrated in Figure 1.2. This shows the initial process of knowledge discovery and framework design, and then application, which will culminate in final communications of outcomes. The audiences and level of technical detail engaged with differs along this engagement process.

Figure 1.2: Overview of the engagement process



How has this paper been developed?

This functional framework paper has been prepared by farrierswier and GridWise Energy Solutions based on:

- initial research of publicly available reports
- interviews with ARENA staff and a technical reference group,[1] and their feedback on an initial draft functional framework

Farrierswier and GridWise Energy Solutions thank all stakeholders for their participation and valuable feedback to date. Various parts of this paper explain how that feedback has influenced the project approach the functional framework.

If you would like to be contacted with project updates and future invitations to provide feedback, please register your interest on the ARENA website. Registering takes one minute, and allows ARENA, farrierswier and GridWise Energy Solutions to contact you with project updates and invitations to provide feedback on the work.

2. Key concepts for the DER technology integration framework

2.1 WHAT IS MEANT BY DER FOR THIS WORK?

There is currently no single widely-adopted definition of DER, with definitions varying depending on the context. For the purposes of this project, the following definition is proposed, which draws on existing definitions used by bodies including the ESB and AEMO and is tailored to the context of this report.

1 The technical reference group consists of key DER sector leaders from eight organisations consulted at various stages during the project to draw on their expertise.

Distributed Energy Resources (DER) are resources connected to the distribution system that generate or store electricity, or actively manage electricity demand.

For the purposes of the report:

- DER includes:
  - Generation and storage connected to a distribution network. Generation or storage can be 'behind-the-meter' (eg rooftop solar PV or household batteries) or in-front-of the-meter (eg a community battery or generation smaller than the threshold for registration). All generation and storage technologies are included, including conventional generation such as diesel generators and potential new technologies such as distributed hydrogen.
  - Electric vehicles and other forms of mobile DER, and related charging or vehicle-to-grid infrastructure and technology
  - Technology used to actively manage a consumer's electricity demand (e.g. hot water load control or smart appliances)
- DER does not include:
  - Energy efficiency or behavioural demand response without any form of technological control
  - Generation and storage systems that are large enough to be required to be AEMO registered participants (ie currently greater than 5 MW in the NEM)
  - Scheduled load registered with AEMO.

The scope of this project is limited to issues relevant to the National Electricity Market (NEM) and/or the Wholesale Electricity Market for the South West Interconnected System of Western Australia (WEM). Projects from other Australian electricity systems will be considered if they provide relevant lessons for the NEM or WEM. The report will only consider the use of DER in interconnected systems, not the use of DER to provide stand-alone power systems.

This definition reflects refinement for feedback

The project surveyed stakeholders on whether the draft DER definition was suitable for our purposes. The draft definition was supported across the technical reference group, and the majority of survey responses replied either 'yes' or 'partially' and provided clarifying feedback. Key feedback and how this paper responds to that feedback is set out in Table 2.1.

Table 2.1: Responding to feedback on the DER definition

Feedback	Response
A third of survey respondents agreed with the definition while the remainder proposed clarifications or small changes	Retain the scope of the definition with targeted refinement for feedback.
Several parties raised the matter of cost efficiency and economic optimisation (nothing that these were general comments that did not specifically relate to the DER definition)	See section 2.2.3
Our draft definition referred to id 'non-registered' resources. Several stakeholders found the 'registered' point either: • Confusing (eg as between generation registration and the DER register), or • Inappropriate because it is not in common DER definitions and registration status of DER may change in future	Remove 'non-registered' from definition. Clarify in the elaborating list of exclusions that DER does not include generation and storage systems that are large enough that they are required to be registered participants (eg a large wind farm connected to the distribution network).
Several stakeholders commented on the demand response element that it was either too broad (eg a number thought it should focus on 'actively' managed demand), or not broad enough (eg should include energy efficiency).	Given the project scope is techology integration, the updated definition is clarified as being for 'actively' managed demand. Passive demand response such as behavioural change for time of use pricing incentives or energy efficiency through efficient housing design does not require the same system integration capabilities.
One participant thought the definition should only be behind the meter	No change because this would constrain the scope of DER integration and impede the ability of the work to deliver on ARENA's objectives by excluding emerging forms of DER such as community batteries.
Some considered the EV description was too narrow and should cover other potential forms of mobile storage	Added storage to the definition, and recognised the potential for other mobile forms of storage in the elaborating examples of inclusions.

2.2 WHAT ARE THE ELEMENTS OF THE FUNCTIONAL FRAMEWORK?

The functional framework uses the following elements to build up each layer of the framework.

Integration topics

The functional framework is organised into four high-level integration topics. These topics are presented as the key technical integration questions that must be answered to achieve a mature state of DER technology integration.

The four integration topics describe different layers of technology, systems and data that are required across various parts of the energy supply chain for effective DER integration:

- **Devices**: What capabilities can DER assets provide to benefit the power system?
- **Communications and interoperability**: How do DER assets communicate and interoperate with each other and broader systems?
- **Understanding DER behaviour**: What data, modelling and analysis is needed to understand DER behaviour and maximise the benefits of DER?
- **Services**: What market and network services can DER deliver?

Functional areas

Each integration topic is divided into multiple functional areas. These functional areas represent the key capabilities that are required for effective DER technology integration.

It is acknowledged that for both the integration topics and the functional areas, it is inevitable that there will be some overlap. This means that some items may not seem mutually exclusive, though the aim remains to ensure that they are collectively exhaustive. As noted already, it also means that the final groupings will be refined both for stakeholder feedback, and for insights gained during the project data collation and maturity assessment.

The range of recognised technical issues to be addressed for DER integration has to date been complicated because there are various frameworks available that have tried to group these at differing levels of technical depth. For example, work by the ESB, DEIP, AEMO, the AEMC and Open Energy Networks have each attempted elements of this. The functional areas set out section 4 seek to recognise and leverage this existing work.

These topics and functional areas reflect refinement for feedback

The technical reference group provided extensive input to refine the initial draft of the functional framework in terms of the number, labelling and scope of the integration topics and functional areas.

When surveyed, stakeholders supported the comprehensiveness of these framework elements and provided feedback that we have incorporated into the detailed descriptions of each functional area in section 4.

While acknowledging the technical nature of the integration task, a number of stakeholders highlighted the importance of communicating how the various areas of functional integration will benefit customers. Section 2.2.1 now explains this.

Different stakeholders questioned if there were other ways of structuring the functional framework, often informed by how their particular organisations participate within the electricity sector. Sector 2.2.2 now explores the alternatives and explains why the capabilities lens has been used.

2.2.1 How does this translate to benefits for consumers?

As noted in section 1.3.1, the objective of DER technology integration is:

> *to enable DER to be utilised efficiently to maximise the benefits for all consumers regardless of whether they have DER.*

The table below illustrates the benefits of effective DER technology integration for consumers and gives examples of how different functional areas benefit consumers and contribute to achievement of this objective. All benefits of DER technology integration (whether they are realised by all consumers or those who chose to participate in DER) stem from removing barriers and limits to DER participation and increasing the benefits that consumers can realise from participating.

Table 2.2: Benefits to consumers from DER technology integration

Benefits for all consumers	Additional benefits for consumers who participate in DER
A more secure, reliable and resilient power system resulting in fewer power outages For example, increased maturity in the *ability to withstand disturbances*, *grid support*, *protection and control*, *cybersecurity*, *DER visibility*, *DER modelling*, *transmission system security and reliability* and *integration with wholesale energy and system security markets* functional areas will improve system security and reduce the likelihood of load shedding or blackouts compared with a scenario where there was not effective DER technology integration	**Less limitations imposed on the connection or export of DER enables DER owners to earn more money from the use of their DER** For example, improved *ability to withstand disturbances*, *grid support*, *protection and control*, *DER visibility*, *DER modelling* and *network hosting capacity* can reduce the extent to which AEMO and distributors need to impose constraints on the amount of DER that can be connected or exported at certain times, which will allow more people to install DER and allow DER owners to earn more money from their DER
Increased use of DER instead of other more expensive forms of generation leading to lower energy prices For example, improved *ability to withstand disturbances*, *grid support*, *interoperability between devices and systems*, *DER visibility*, *DER modelling*, *network hosting capacity* and *integration with wholesale energy and system security markets* will enable increased amounts of DER to be used to generate electricity or manage demand as a lower cost alternative to using traditional centralised forms of electricity generation	**Increased revenue from DER by enabling DER owners to access new value streams** For example, improved *integration with wholesale energy and system security markets* and *provision of localised network services* will enable DER service providers and their customers to access new markets and be paid for providing an increased range of DER services
More efficient operation of networks leading to lower network costs and lower energy prices For example, increased maturity in the *integration of DER within AEMO's and distributors' systems*, *DER visibility*, *DER modelling*, *distribution system reliability and power quality* and *provision of localised network services* functional areas can enable distributors to operate their networks more efficiently and reduce costs, including by using DER services as a lower cost alternative to traditional network expenditure	**Opportunities for service providers to offer new or improved services to customers with DER** For example, increased *interoperability between devices and between devices and systems*, *cybersecurity*, *DER visibility*, *DER modelling*, *integration with wholesale energy and system security markets* and *provision of localised network services* will enable DER service providers to offer customers improved data and new services to help them use their DER to manage their energy consumption, reduce their energy costs and maximise the value of their DER

Benefits for all consumers	Additional benefits for consumers who participate in DER
Increased use of renewable energy and lower emissions For example, increasing the maturity of functional areas such as *ability to withstand disturbances*, *grid support*, *interoperability between devices and systems*, *DER visibility*, *DER modelling*, *network hosting capacity* and *integration with wholesale energy and system security markets* will enable increased amounts of demand response or renewable energy based DER such as aggregated household solar PV and batteries to be used instead of centralised coal or gas generation	**Confidence in data and communications systems privacy and security** For example, robust *cybersecurity* for the various device to device and device to market, grid and service provider communications systems that will be required in a high penetration, active and integrated DER system will be important in building consumer confidence in both buying and selling DER services in the future.

2.2.2 Why use a capabilities focus?

There are many ways this project could attempt to breakdown and organise the DER integration functional framework. These will have differing appeal to different stakeholders. Feedback received shows that this may depend upon how each stakeholder views and interacts with the electricity supply chain, eg research and oversight institutions, incumbent and new entrant infrastructure and service providers within the supply chain, and customers buying existing and new energy services.

So much of Australia's energy policy and regulation is framed by reference to the component parts of the traditional supply chain, eg the wholesale market for and transmission system for bulk power supply, distribution, retail, metering, and behind the meter. However, perpetuating this framing can be unhelpful when the supply chain participants, their scope, and with whom, how and when they need to interact has to change to enable effective DER integration.

Realising the full range of benefits in the DER value stack could encompass services with benefits that may accrue to a particular participant in the traditional linear supply chain. However, the functional capabilities to realise these mostly involve a one-to-many integration that breaks the linear chain (eg data communication, DER visibility and predictability, and access to control or dispatch DER devices).

This means that the linear supply chain view, while appealing where it works for benefits (and some problems), is not as useful for considering integration and coordination in a future of high DER penetration and improved integration.

Indeed, not forcing stakeholders to recognise this feature of transformation could perpetuate the frustration of dealing with the traditional supply chain paradigm and a legacy regulatory regime inherently founded on that paradigm and the physics of its operation.

So, what about a customer services view of integration as an alternative framing? This is an important view which Section 2.2.1 seeks to explain. However, it is unlikely to be a view capable of solving the integration question or assessing progress on technology maturity.

The objective of DER technology integration is to realise the benefits of customers' DER investments and activities. Achieving this necessarily involves reforming the sector to enable the potential elements of benefit within a maximised DER value stack to be realised.

The capabilities that we have identified have been informed by a customer perspective. We have set out those capabilities that are necessary for all customers to obtain the maximum benefit from DER, eg in terms of reducing costs or maintaining security and reliability. This project's objective is to identify the capabilities that are required to enable DER to be effectively integrated so that it benefits all consumers, regardless of whether they have DER. This objective is broader than that proposed by some stakeholders who suggested the focus should be on how to maximise the value derived by those consumers who install DER or to enable all consumers to install DER.

Realising the DER value stack for customers requires technical examination of the scope and mechanisms of technology, systems, data and financial transactions that occur within the energy supply chain. Customers do not see or participate in that complexity today.

Once DER integration is resolved technically, various energy suppliers will design energy products and services, some of which we cannot yet imagine. Working within a brief to technically facilitate these future services '*in the background*' is why the project is focussing on technical capabilities.

2.2.3 Why isn't this project assessing economic optimisation?

Economic optimisation is an important consideration codified in the National Electricity Objective. So understandably, some stakeholders who were consulted asked why economic optimisation is out of scope.

As noted above, the DER technology integration scope will provide a physical enabler of the DER integration objectives. It is not exhaustive of the work needed to achieve effective DER integration, so this work will contribute to and complement other work looking at broader market and economic considerations.

The 'non-optimised' scope for assessing DER technology integration ensures a focus on:

1. identifying the necessary enabling capabilities, and
2. assessing the current maturity of these enabling integration capabilities.

Optimisation can be considered when either the capabilities are known to exist or when directing resources towards the identification of or maturity progression of missing or immature capabilities.

This delineation makes sense within the context of ARENA's role. ARENA's purpose is to improve the competitiveness of renewable energy technologies and increase the supply of renewable energy through innovation that benefits Australian consumers and businesses. It has a current investment priority of '*integrating renewables into the electricity system*' which means it will apply its systematic funding prioritisation to identify and then lower the costs of viable technologies, products and processes that can facilitate this priority.

ARENA has a track record of facilitating material reductions in technologies it targets. Therefore the project's focus on '*how can it be done physically?*' and '*what are the maturities of the capabilities required for this?*', is a necessary first step ahead of asking '*can it be done cheaper?*.

This technology feasibility and capability requirement step is all the more important where Australia's energy market is not optimised for a single outcome. The National Electricity Objective requires co-optimisation of security, quality, reliability, price and safety. Different options for delivering DER integration capabilities will contribute to or detract from these objectives to varying extents.

2.3 HOW HAS EACH FUNCTIONAL AREA BEEN DESCRIBED?

Section 4 includes a summary of each of the 13 functional areas identified. A table for each functional area sets out:

- A short **description of the functional area**
- **Specific issues** that are contained within the functional area
- The **capabilities** that are expected to be desirable to achieve full maturity of the functional area.
- The **key constraints** identified so far that limit the achievement of those capabilities.
- The **consequences if the desirable capabilities are not achieved**, expressed from the perspective of the integration objectives and the impact on consumers.

The information on capabilities, constraints and consequences has been included to help inform the maturity assessment that will be undertaken at a later stage of the project.

The report that is produced at the end of this project is intended for a broad audience including non-technical stakeholders with limited background knowledge. The tables are accordingly reasonably high-level and focus on capabilities and outcomes rather than detailed descriptions of specific technologies.

It is recognised that the level of detail included in the tables varies between different functional areas. This largely reflects the relatively early stage of the work and that the amount of publicly available information for us to draw on in preparing this paper is limited for some functional areas. Your feedback on this paper and subsequent stages of the project will help to develop more comprehensive information on each area. This project is intended to be a collaborative process where the final report is informed by extensive stakeholder input and information on the projects that are reviewed.

Desirable capabilities for full maturity

The term "desirable capabilities for full maturity" has been used instead of alternatives such as "required capabilities" or "optimal end-state" to recognise that not every functional area may currently have a clear end-state and that not all of these capabilities may be essential in the short-term or in every location. In some cases, it may not be feasible or efficient to deliver all of these capabilities in the foreseeable future. In addition, some of the capabilities may not be relevant or necessary for all forms of DER.

In some cases, the desirable capabilities may not yet be known. In other cases, the desirable capabilities may be contested, with stakeholders having different views regarding the set of capabilities that are required and the desirable level of maturity of those capabilities. For example, there are differing views regarding the level of visibility and control of DER devices that AEMO, network operators and other parties require to maintain security and reliability.

There are also likely to be trade-offs between the capabilities and maturity levels required in different functional areas, for example improved DER visibility, DER modelling and market integration may reduce the need for certain device capabilities or the level of control over devices that is needed to maintain security and reliability.

The description of the functional areas and desirable capabilities should not be interpreted as suggesting that the objective is to achieve full maturity in all areas as soon as possible across all parts of the NEM and WEM. An assessment of costs and benefits is required to assess whether it is efficient to close identified maturity gaps, with the outcomes of that assessment likely to vary across different locations depending on factors such as the level of DER penetration.

2.4 HOW WILL THE FUNCTIONAL FRAMEWORK BE USED?

Understanding how the functional framework is intended to be used may aid in understanding it conceptually.

The functional framework is now being used in the next stage of work to assess how far the identified projects collectively progress maturity of the required DER integration capabilities in each functional area.

Farrierswier and GridWise Energy Solutions are applying a fit-for-purpose maturity assessment method which is being designed so that ARENA can apply it annually to assess future progress in advancing DER technology integration.

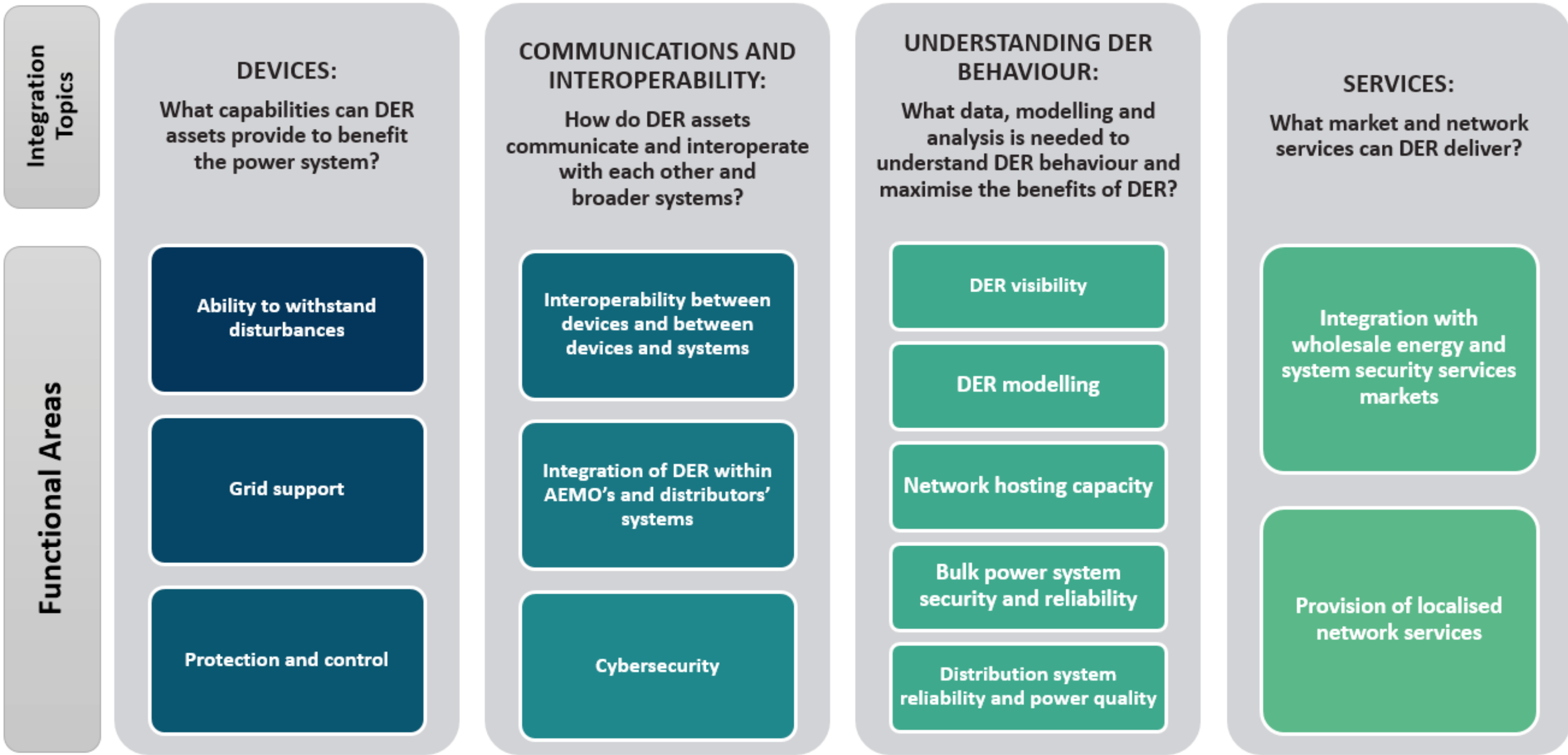
The maturity assessment is being performed for each of the functional areas described in section 4. This means individual projects are not being assessed, but rather their collective contribution to maturity for each functional area. Maturity is being considered based on both: the projects'/programs' collective scope (ie as though they are finished) as well as based on progress to date (ie where we stand today).

In performing this inaugural assessment, farrierswier and GridWise Energy Solutions will:

- Note what cannot be assessed from a maturity perspective yet from the assessed projects for the 13 functional areas, and where evident, also note what information would be needed to enable assessment in future.
- Note where there is a recognised regulatory constraint frustrating the maturity of a capability. For example, where technology may otherwise be considered mature in isolation (eg due to its commercial availability) but regulatory settings are leading to inadequate scale deployment or to this functionality being disabled or not widely utilised.
- Note where a mature technology solution is available, but it has not seen widespread deployment due to consumer preferences or a need for further social and market research to support the uptake of DER technologies.

3. Functional framework

DER TECHNOLOGY INTEGRATION FUNCTIONAL FRAMEWORK



4. Functional area descriptions

4.1 DEVICES

Functional area	Ability to withstand disturbances
Description of the functional area	The ability of DER devices, individually or when aggregated, to adequately respond to and withstand (ie not disconnect during) power system disturbances, thereby not exacerbating power system security issues
Specific issues included in the functional area	DER capabilities and device standards related to: • Voltage disturbances, both over and under voltage disturbances • Frequency disturbances caused where frequency deviates above or below nominal frequency of 50 Hz • Disturbances causing large phase angle shifts (or jumps) typically caused by changes in network configurations or other large system events such as interconnector trips • Fault ride through capability (single and multiple) – the ability of DER to withstand and not disconnect during faults of various kinds in the vicinity of the connection point, including multiple coincident disturbances • Continuous uninterrupted operation of DER for voltage fluctuation, harmonic voltage distortion and voltage unbalance conditions Consideration of agility and prescriptiveness of standards is necessary given the pace of technological change. Grandfathering of older standards also needs to be considered.
Desirable capabilities for full maturity	DER devices comply with applicable standards and can be expected to withstand power system disturbances similar to requirements placed on large scale generation. Examples include: • Ability to withstand over-voltage conditions (eg: as per NER clause S5.1a.4) • Zero voltage ride through • Frequency deviations of magnitude and durations as described in the NEM mainland and Tasmanian frequency operating standards • Voltage fluctuations and harmonic voltage distortion levels up to the levels in AS/NZS 61000.3.7 and 61000.3.6 respectively
Key known constraints on achieving desirable capabilities	• Device vendors need consistent guidance on disturbance withstand capabilities and these need to be aligned not only across networks and jurisdictions in Australia but also largely match global trends (eg with the revised IEEE 1547 standard) • AEMO and Network Service Provider (NSP) requirements need to be coordinated • Inherent limitations in some of the DER technologies (eg short circuit current contribution by solar PV inverters) needs to be mitigated and managed • Advanced capabilities that are available in inverters need to be effectively utilised by NSPs by including them in connection processes and technical assessments and improving back-end systems and processes • Advanced inverters have some of these capabilities, but some have not been set up correctly during installation or have been changed during ongoing operations. Compliance verification is important

Functional area	Ability to withstand disturbances
Consequences if desirable capabilities not achieved	Inadvertent trips of DER during power system disturbances could potentially make the overall power system less secure by exacerbating disturbances. The issue is compounded if NSPs and AEMO do not have sufficient visibility of DER and accurate DER models. One consequence would be operating margins would need to be increased, resulting in less DER being able to connect and, if connected, it may be constrained under some system conditions

Functional area	Grid support
Description of the functional area	The ability of DER devices, individually or when aggregated, to respond to power system phenomenon in a manner that (1) limits or prevents any adverse impacts caused by the DER themselves and (2) provides additional grid support that benefits overall grid security and reliability
Specific issues included in the functional area	• Frequency control: DER's ability to respond autonomously to changes in system frequency, through mechanisms such as Primary Frequency Control (PFC) • Voltage control: DER's ability to provide voltage / reactive support autonomously to changes in local area voltages, whether they are distribution, sub-transmission or transmission level nodes • Participation and coordination with existing and potential new under-frequency load shedding schemes to maintain system security
Desirable capabilities for full maturity	DER can be expected over time to provide grid support capabilities similar to large scale inverter connected generation and possibly some characteristics similar to synchronous generation. Examples include the ability to: • Respond to under-frequency events and adjustable / settable frequency droop characteristics • Switch reactive power / voltage control modes and co-optimisation of local area (eg distribution feeder) and wide area (eg transmission substation) voltage profiles • Follow centralised dispatch instructions, particularly at an aggregate level • Provide system strength support, grid-forming capabilities, synthetic inertia
Key known constraints on achieving desirable capabilities	• Device vendors need consistent guidance on the required grid support functionalities and these need to be aligned not only across networks and jurisdictions in Australia but also largely match global trends • The requirements of AEMO, NSPs and retailers need to be coordinated and clearly specified so that available device capabilities are activated, eg Australian Standards require some capabilities to be disabled unless required by DNSP connection requirements and not all DNSPs have required enablement of those capabilities • Many of the grid support features can only be utilised when further improvement on inter-operability of systems is achieved • Participation in grid support will be incentivised through development of corresponding markets • New DER devices can be required to meet the latest standards at the time of installation, but existing devices will continue to operate under older standards until they are replaced. Suitable grandfathering arrangements need to be in place.
Consequences if desirable capabilities not achieved	As DER penetration increases and it replaces larger scale generation, particularly synchronous generation, the ability of DER to maintain power system security becomes critical. Whole of system costs to operate the grid increase without DER grid support. System reliability may be reduced and NSPs or AEMO may need to limit or constrain DER generation

Functional area	Protection and control
Description of the functional area	The ability of the DER, particularly inverter connected DER, to coordinate its device protection with upstream feeder and transformer protection
Specific issues included in the functional area	• Coordination with feeder, transformer and zone substation protection to prevent maloperation • Anti-islanding protection with appropriate redundancies • Remote coordination, monitoring and control of protection settings This functional area only covers the device capability aspects of protection and control. Issues related to the integration of DER into AEMO's and distributors' protection and control systems are covered in the "Integration of DER within AEMO's and distributors' systems" functional area
Desirable capabilities for full maturity	This functional area has received considerable attention from both device vendors and networks as DER penetration has been increased over the past few years. For example, the AS/NZS 4777.2 update in 2015 included requirements for inverter anti-islanding and disconnection functions to prevent islanding. Further maturity of this area will include some of the below: • Future proofing upstream network protection systems for rapid DER uptake • Robust and flexible set of solutions to adapt to a range of DER characteristics and penetration levels • Mechanisms for N-1 redundancy of anti-islanding protection • Procedures for compliance testing and coordination with DNSP work practices
Key known constraints on achieving desirable capabilities	• Significant work has been done on protection related device standards, especially with the AS 4777.2 revisions. However, assessing locational or jurisdictional differences for high DER uptake remains a critical ongoing issue as DNSP standards and compliance assessment processes can vary • DER visibility, both from a static (at time of installation) as well as dynamic (status, export) perspective will be important so that DNSPs and AEMO can properly assess and implement protection upgrades and setting changes and ensure consistency between device settings and their systems • Contingencies for failure of communication, either due to an outage or intentional maloperation (eg the DER owner disconnecting communications or changing settings)
Consequences if desirable capabilities not achieved	• Maloperation of network protection can cause inadvertent trips of DER leading to lost revenue or missed opportunities for DER owners • Similarly, if protection fails to operate, it could cause significant problems for networks in terms of safety (potential injury) and reliability (degradation of network assets)

4.2 COMMUNICATIONS AND INTEROPERABILITY

Functional area	Interoperability between devices and between devices and systems
Description of the functional area	The ability of all parties who need to interact with DER devices to communicate and exchange information with those devices and with each other. This includes a common understanding between parties regarding what information will be shared, the format for the information and how it is to be used
Specific issues included in the functional area	• The systems and processes required to enable all relevant parties to communicate and exchange information with DER devices and with each other to maintain the security and reliability of the electricity system and facilitate the participation of DER in markets. This includes remotely changing device settings, monitoring device operation and enabling the coordinated control of devices • The systems and processes required to enable DER aggregators and service providers to orchestrate large volumes of DER devices and to provide DER customers with information to help them maximise the value of their DER • The systems and processes required to communicate network operating envelopes to DER aggregators and service providers to facilitate maximum utilisation of DER without breaching network technical limits. "Operating envelopes" are the technical limits DER must operate within to maintain security, reliability and power quality • Telecommunications network requirements to enable the communication of this information at an appropriate speed, quality and level of reliability • Protocols for defining the data to be exchanged and the format for that data • Application programming interfaces (APIs). APIs are the routines, protocols and tools that allow different software applications to talk to each other
Desirable capabilities for full maturity	• Agreement on who can communicate what information with DER devices and in what format • Communications systems, standards and protocols are consistent, open and interoperable so relevant parties can communicate with devices and each other • Relevant international and overseas standards set out capabilities that may be desirable, but additional work is required to understand their applicability in the Australian context and prepare guides for their implementation (if adopted here), including IEEE standards 1547 and 2030.5

Functional area	Interoperability between devices and between devices and systems
Key known constraints on achieving desirable capabilities	• There is not currently agreement on the communications and interoperability capabilities that are required for efficient DER integration • The vast majority of inverter-connected DER devices are already communications-enabled, but there is limited specification and consistency around the communications standards and protocols required so that the capability that exists within devices can be effectively utilised • Proprietary communications systems and restrictions imposed by some manufacturers limit who can communicate directly with DER devices • Australia's size means overseas equipment manufacturers are unlikely to design equipment to meet Australian specific interoperability standards • Successful DER integration is likely to require time-sensitive access to large volumes of network and DER data. Current telecommunications networks may not be able to meet these requirements, particularly in rural and regional Australia where telecommunications networks are less advanced than in major urban centres and outages (planned and unplanned) are typically longer. Different technology approaches to deal with these shortfalls are necessary.
Consequences if desirable capabilities are not achieved	If there is limited ability to communicate with DER devices and exchange information between parties: • the power system may need to be operated more conservatively • DER device capabilities will be not be able to be fully utilised to maintain or improve system security, reliability and power quality • DER will not be able to fully participate in markets and be rewarded for that participation

Functional area	Integration of DER within AEMO's and distributors' systems
Description of the functional area	The system and infrastructure (eg IT) requirements necessary for AEMO and network service providers' systems to utilise the capabilities provided by DER and manage the potential impacts of DER in a coordinated and integrated manner
Specific issues included in the functional area	The impact of high DER penetration and its grid integration requirements needs to be assessed in relation to changes to existing enterprise and market systems, and could lead to the introduction of new systems. AEMO's and NSPs' systems need to be capable of effectively utilising new capabilities DER can provide. Relevant systems and issues include: • AEMO's Energy Management System (EMS) and NEM Dispatch Engine (NEMDE) • NSPs' Advanced Distribution Management Systems (ADMS), including potential Geographic Information System (GIS) and Outage Management System (OMS) upgrades) • Supervisory Control and Data Acquisition System (SCADA) upgrades • potential future distribution system operator (DSO) and/or distribution market operator (DMO) systems
Desirable capabilities for full maturity	• Inclusion of a DER management system (DERMS) or similar platform and its full integration with NSP ADMS systems (eg coordination with Outage Management Systems) or suitable alternative approaches are needed to organise the operation of large volumes of aggregated DER • Standardised APIs, data sets and communications protocols will need to be commonly agreed and integrated within utility enterprise systems • Retailer and third party software platforms for DER aggregation are able to effectively integrate into AEMO's systems and potentially DNSPs' / DSOs' systems
Key known constraints on achieving desirable capabilities	The current systems used by AEMO and NSPs have been developed over the past few decades by major international vendors. As DER technology evolves rapidly and associated market mechanisms change, the operational systems also need to adapt rapidly. The cost and complexity of adapting legacy systems and add new systems is a significant constraint.
Consequences if desirable capabilities not achieved	As DER penetration increases and it substitutes for larger scale generation, particularly synchronous generation, ability of DER to maintain power system security becomes critical. Whole of system costs to operate the grid increase if AEMO and NSP systems do not take into account and manage the impacts of DER in a coordinated and integrated manner

Functional area	Cybersecurity
Description of the functional area	The protection of devices and systems from theft or damage to the hardware, software or information on them or the misuse of the services they provide. Cybersecurity can also include the resilience of the system to large-scale DER outages, malfunctions or unexpected behaviour that has the potential to jeopardise the safe and secure operation of the electricity system
Specific issues included in the functional area	• Preventing, detecting and responding to attacks on DER devices and the systems they interact with, including the systems of customers, DER vendors, AEMO, network operators, aggregators, energy service providers and communications providers • Protecting, detecting and responding to risks of large-scale DER outages, malfunctions or unexpected behaviour that could cause impact on the safe and secure operation of the electricity system • Protecting the information contained in those devices and systems and the services they can provide against harm that may arise from unauthorised access
Desirable capabilities for full maturity	• DER devices and systems they interact with are protected from cybersecurity threats, including the systems of AEMO, network operators, aggregators, energy service providers and communications providers • It would be desirable to develop a cybersecurity framework for DER devices and the systems they interact with, or extend an existing framework to address those issues, including undertaking regular assessments of cybersecurity capability, maturity and risks. For example, the Australian Energy Sector Cyber Security Framework (AESCSF) has been developed by AEMO, the Australian Cyber Security Centre, Critical Infrastructure Centre and the Cyber Security Industry Working Group.The AESCSF contains maturity indicator levels, security profiles and a criticality assessment tool for assessing the cybersecurity capability and maturity of participants in the energy sector. The AESCSF does not currently specifically address DER cybersecurity issues
Key known constraints on achieving desirable capabilities	• Connecting millions of communications-enabled DER devices significantly increases cybersecurity risks. Cybersecurity has long been a key issue in energy systems, but was previously easier to manage due to the much smaller number of devices that could interface with AEMO's and network operators' systems and the more isolated and analogue environment of distribution systems where network operators had greater control over devices connected to their systems • Increasing maturity levels in other functional areas related to interoperability and market integration will further increase the potential cybersecurity risks • Utilising the AESCSF, market participants across the NEM and WEM have undertaken self-assessments of the current state of maturity of their cybersecurity capabilities. AEMO's December 2018 report on these assessments identifies opportunities to improve cybersecurity maturity across the sector
Consequences if desirable capabilities are not achieved	DER devices and the systems of AEMO, network operators and other parties who interact with DER devices could be vulnerable to cyber-attacks. The consequences of those attacks could not only impact energy consumers and energy organisations, but also have serious broader impacts to society, public health, safety and the economy

4.3 UNDERSTANDING DER BEHAVIOUR

Functional area	DER visibility
Description of the functional area	The ability to monitor where DER is installed and how it is capable of behaving in real-time so the benefits of DER can be maximised and the potential impacts on the local distribution network and the wider electricity system can be managed. This functional area includes what data is needed and how is it captured and stored
Specific issues included in the functional area	• Static parameters: DER parameters that remain unchanged throughout their asset life. These include installed capacity, technology type and connection point • Long term dynamic monitoring: DER parameters that can change over their lifetime but less frequently • Short term dynamic monitoring: DER parameters that can frequently and are relevant for monitoring power system security, eg real time power output, voltage and battery state of charge • The level at which visibility is required, eg individual devices or meter / connection point level, which will affect the type of data that is required and the source of that data (eg inverters, smart meters, network equipment). The desirable level of visibility may depend on maturity of other functional areas, eg increased market integration can reduce the need for visibility of individual DER devices versus visibility of aggregated generation and demand at the connection point
Desirable capabilities for full maturity	• Monitoring devices that improve visibility and the requisite quality windows that are reliable and verifiable need to be commonly understood and applied • Systems and processes for maintaining a DER register documenting DER parameters at the time of installation • Communication protocols and frameworks for accessing information on DER dynamic parameters on an ongoing basis. This will involve further development of interoperability standards and market frameworks, eg for device-to-cloud and cloud-to-cloud data exchange. Privacy and cybersecurity requirements need to be considered
Key known constraints on achieving desirable capabilities	• There is not currently agreement on what types of DER information is required and who should have access to that information. AEMO's DER register only contains static information and can only be accessed by AEMO, DNSPs and emergency service agencies • There is currently some ambiguity as to what data can be exchanged between different parties due to privacy or data ownership concerns • DER technology vendors' competing commercial interests may limit access to DER data • Future market frameworks will influence the level of visibility that is needed and the structures under which data will be accessed and shared with relevant parties. The details of such frameworks will need to be confirmed so that the technical constraints can be identified and resolved, eg which parties require access to what types of data and at what level of granularity and regularity • Managing the large volume of DER data in an accessible manner and then keeping it current on an ongoing basis is a significant challenge

Functional area	DER visibility
Consequences if desirable capabilities not achieved	Without accurate information on DER status and key technical parameters, it is not possible to maximise DER utilisation without breaching network technical limits, resulting in either: • increased risks to reliability, security or power quality; or • to avoid those risks, AEMO and DNSPs imposing more conservative static limits on DER utilisation, which can increase energy prices for all consumers and reduce owners' returns

Functional area	DER modelling
Description of the functional area	All aspects of data validation and models necessary to assess the technical impacts and benefits of DER at an individual level and in aggregate, including integration of DER models within broader system models
Specific issues included in the functional area	DER models (including probabilistic/stochastic models where relevant) are necessary for the following applications: • Assessments by DER investors and operators • Planning assessments (eg assessing connection performance standards, resource adequacy) • Long term operational assessments (eg summer preparedness) • Short term operational assessments (eg from daily generation and load forecasts down to seconds) • Load flow and Electromagnetic Transient (EMT) models to assess system security • NSP planning and forecasting models and processes • Assessing the impact of DER on system security and overall power system resilience
Desirable capabilities for full maturity	The technical assessments for evaluating the risks and opportunities presented by DER can only be conducted when accurate models with the right level of precision are available. These models also need to be fit for purpose. Some examples are: • Steady-state and dynamic representation of DER inverter characteristics for network planning purposes • Short term and long term forecasts for DER native generation and export at the connection point are necessary for operational planning, including how DER generation is affected by events such as cloud cover and the impacts of potential DER mal-operation or unpredicted operation • Detailed EMT models are necessary for assessing complex system security issues related to system strength and post-event analysis • Visibility of the LV network is required for monitoring the impacts of DER, including related upgrades to DNSPs' SCADA and GIS systems • Understanding the likely behaviour of customers with DER in order to better understand how DER is likely to be installed and used
Key known constraints on achieving desirable capabilities	• DER modelling is an evolving technical area and significant research and practical project experience (through trials etc) is essential before integration within standard network planning and operational processes • DER visibility and access to key data is a significant limitation, which needs to be resolved before accurate models can be developed • Australian LV networks are large and complex, and significant resourcing and effort is required to accurately model them and the impact of DER on them • Upgrades to AEMO's and NSPs' technical processes, software systems etc will likely be needed as DER penetration increases

Functional area	DER modelling
Consequences if desirable capabilities not achieved	Without accurate information on DER status and key technical parameters, it is not possible to maximise the utilisation of DER without breaching network technical limits. The result will be either: • increased risks to reliability, security or power quality; or • to avoid those risks, DNSPs and AEMO will impose more conservative limits on DER utilisation, which will increase energy prices for all consumers and reduce returns for DER owners.

Functional area	Network hosting capacity
Description of the functional area	Determining and communicating the amount of DER that can be accommodated within a DNSP’s network, or the relevant part of the network, without adversely affecting thermal and voltage limits, power quality and reliability
Specific issues included in the functional area	Technical issues that limit DER hosting capacity of distribution networks include the thermal ratings of network components, voltage regulation, short circuit level and power quality considerations, while additional constraints may arise from islanding considerations and the possibility for reversal of power flows. The functional area will also assess how the following impact hosting capacity and can be better understood to maximise the amount of DER that can be accommodated: • Visibility and management of network constraints • Long term hosting capacity • Defining network constraints and “operating envelopes” for safe, secure and reliable power system operations The assessment and communication of hosting capacities on a static and dynamic (time varying) basis is a critical issue to be evaluated and addressed in this functional area.
Desirable capabilities for full maturity	• Improved state estimation methodologies, particularly for the LV networks to assess networks’ operational conditions • Better utilisation of data from a variety of sources (including DER installations, metering data and substation level measurements) to calculate the operating envelopes for DER • A portfolio of technical solutions for managing LV network constraints caused by high DER penetration. These may use conventional approaches such as adjustment of transformer taps or more complex distribution grid storage solutions
Key known constraints on achieving desirable capabilities	• Availability of accurate DER and network data (both static and dynamic) data is a key constraint • Significant additional effort through research and demonstration projects is needed to validate uniform and consistent hosting capability calculations across various jurisdictions • Mechanisms for effective communication of hosting capability limitations and opportunities to aggregators, consumers and the wider market need to be developed • Improvement in hosting capabilities can be achieved through network investment or improved network tariffs, which involve regulatory policy and social equity issues regarding the appropriate method for cost-recovery that need to be resolved
Consequences if desirable capabilities not achieved	Without accurate hosting capability information, there is risk that: • consumers and market participants may make inefficient investments that do not deliver their expected value • AEMO and NSPs may need to operate the grid with higher levels of operating margin and constrain DER for lack of better information • NSPs will not have sufficient information to assess the costs and benefits of expanding network hosting capability • whole of system operating costs and electricity prices may increase

Functional area	Bulk power system security and reliability
Description of the functional area	The technical processes and methodologies required by TNSPs and AEMO to adequately assess the operational impact of DER both individually and in aggregate and how DER can contribute to overall system security, reliability and resilience
Specific issues included in the functional area	Operational impacts of DER on system security, reliability and resilience in relation to: • Frequency control and support • Voltage management • System strength • Managing minimum load • Dispatchability and ramp rates • Impact on under-frequency load shedding (UFLS) systems • System restoration This area includes understanding the impact of system security and reliability issues on the level of DER that the system can support (eg the impact of inertia, fault levels, protection schemes and line configurations) and what actions could potentially be taken to facilitate higher levels of DER penetration
Desirable capabilities for full maturity	TNSPs and AEMO will need to have capabilities, in a high DER scenario, to assess how DER impacts important power system parameters such as frequency and voltages. The assessment methodologies and related technical processes need to be robust enough to evaluate not only any adverse impact but also maximise the value provided by DER in supporting grid security and reliability. Improvements may include: • Including DER in FCAS and operating reserve calculations • Real time dispatch of DER to manage thermal, voltage or stability constraints • Including DER in constraint equations and having the ability to impose dynamic constraints on DER outputs • Accounting for the impact of DER in UFLS schemes
Key known constraints on achieving desirable capabilities	Integration of DER in system operations is a complex technical area and heavily depends on the type of DER, level of penetration and the nature of the power system it is connecting to. Significant experience needs to be gained through research, pilot/demonstration projects and international benchmarking to include DER on par with large scale generators as a means to manage the power system within defined operational parameters
Consequences if desirable capabilities not achieved	As DER penetration increases and it substitutes for larger scale generation, particularly synchronous generation, the ability of DER to maintain power system security becomes critical. Whole of system costs to operate the grid increase if DER devices cannot be controlled and managed

Functional area	Distribution system reliability and power quality
Description of the functional area	The technical processes required by DNSPs to maintain local distribution network power quality related to voltage fluctuations and harmonic voltage or current distortions and enable more efficient management of distribution network reliability and power quality
Specific issues included in the functional area	• Over-voltage conditions: Current voltage levels across many parts of distribution networks are often higher than the 230V nominal voltage standard, which can affect all customers including those with DER. Generation from DER devices can further increase voltage levels if high voltages are not addressed through network management techniques • Under-voltage conditions: DER generation can increase voltage range, leading to under-voltage in various sections of distribution feeders • Voltage flicker: Intermittency of solar PV based DER can result in voltage flicker outside of prescribed limits • Harmonics: Power electronics based inverters cause voltage and current harmonics that can damage network and customer equipment • Operation of DER in a microgrid during 'island' mode
Desirable capabilities for full maturity	• DNSPs' assessment methodologies and related technical processes need to be robust enough to evaluate network reliability and power quality in a high DER scenario to manage requirements within established standards such as AS/NZS 61000. Desired capabilities include: – Ongoing (near real time) monitoring of power quality parameters across the distribution network and assessment of major contributors to any power quality degradation – A portfolio of short term operational and longer term planning level solutions to minimise any adverse impacts. These solutions could be through load management, consumer pricing signals, network reconfiguration and installation of new network assets (eg voltage regulators, harmonic filters etc) • An understanding of the resilience of distribution networks and the ability of DER to support the grid during severe weather events or other events resulting in large network outages, including the operation of DER microgrids in island mode • DER and network safety protocols need to be consistent.
Key known constraints on achieving desirable capabilities	• The visibility of DER, models of distribution LV networks and appropriate assessment models are currently active areas of research, demonstration projects and new technology developments. As these areas mature, DNSPs will be in a better position to assess LV network power quality and reliability issues and propose solutions. • Smart meters can provide valuable data to improve the visibility of low voltage networks and manage voltage issues, but most small customers outside of Victoria do not currently have smart meters. Similarly, the back end systems and processes needed to maximise value from smart meter data have been slow to develop. • Traditional DNSP practices for system planning and operations (eg: LV voltage management) may need to be revisited and updated on a case by case basis

Functional area	Distribution system reliability and power quality
Consequences if desirable capabilities not achieved	• Poor LV network power quality issues result in damage to network and consumer equipment, eg due to excessive total harmonic distortion. This would also reduce network asset life and degrade network reliability • Other power quality issues such as voltage flicker can result in a poor consumer experience, not just for those with DER but also other customers. If this is not adequately addressed, it would result in lower customer satisfaction and DER uptake could reduce

4.4 SERVICES

Functional area	Integration with wholesale energy and system security services markets
Description of the functional area	The ability for DER to participate in current and future markets for wholesale energy and system security services
Specific issues included in the functional area	• This functional area relates to discretionary services the DER owner/operator can choose to provide by participating in markets and be paid for doing so, as opposed to mandatory requirements imposed on DER devices • Technology and data required to enable participation by DER in current and future markets for: – wholesale energy, including the spot market, derivatives markets and potential future ahead markets or two-sided markets – ancillary services, including contingency and regulation frequency control and ancillary services (FCAS), system restart and ancillary services (SRAS), and potential future markets for new services such as fast FCAS or inertia – reserves, including the Reliability and Emergency Reserve Trader (RERT) and any future operating or strategic reserves • Technology and data required to enable aggregated DER to participate in these markets through a virtual power plants (VPP) utilising a range of participation models (e.g. device-level response, central dispatch, retail models third-party aggregators etc.) • Technology, data and communication protocols required to enable various forms of demand response to participate in these markets
Desirable capabilities for full maturity	• Technology and data are available to enable all forms of DER to participate in these markets, and be rewarded for doing so, to the extent that DER owners/operators wish to participate in these markets, and it is efficient and feasible to enable them to do so. It is unlikely that individual DER devices/owners will directly participate in these markets, but aggregators and other DER service providers should be able to participate in these markets on behalf of DER owners • Demonstration of the standard to which DER can provide these services and interact with the market, such as the ability to respond to power system events, price signals and/or dispatch instructions from AEMO
Key known constraints on achieving desirable capabilities	• Additional evidence is required of the ability of some forms of DER to provide some of these services to the standard required by AEMO, eg the ability of VPPs to provide regulation FCAS and the ability of DER to provide SRAS • High-speed communications between the market operator or third party platform and aggregators or DER devices are currently required to provide some of these services • Advances in data and technology are required to enable accurate and cost-efficient scheduling and settlement of small-scale forms of demand response
Consequences if desirable capabilities are not achieved	If DER cannot participate effectively in these markets, there will be less providers of these services and could be corresponding detrimental impacts on: • System security and reliability, particularly as DER penetration increases and large-scale generators that have traditionally provided ancillary services retire • Energy prices for all consumers, as the costs of these services is higher due to less competition • Returns earned by owners of DER

Functional area	Provision of localised network services
Description of the functional area	The ability of DER to provide services to NSPs to enable them to operate their networks more efficiently and/or maintain or improve reliability and power quality
Specific issues included in the functional area	Technology and data required to enable DER owners, operators or aggregators to provide services to DNSPs, and where relevant TNSPs, to: • reduce network costs by avoiding or deferring transmission or distribution network augmentations • reduce thermal or voltage constraints • improve network reliability • improve power quality This functional area relates to discretionary services the DER owner/operator can choose to provide to NSPs be paid for doing so as opposed to mandatory requirements imposed on DER devices
Desirable capabilities for full maturity	Technology and data are available to enable all forms of DER to provide a broad range of services to DNSPs, and where relevant TNSPs, and be rewarded for doing so
Key known constraints on achieving desirable capabilities	• DNSPs are in the process of developing a full understanding of the technology, data and services required to support network operation with high levels of DER penetration and the most efficient way of providing those services. A variety of technology options are possible, with different DNSPs currently trialling different approaches • Most services that are valuable to NSPs require the aggregation of large amounts of DER • Additional evidence is required of the ability of some forms of DER to provide some of these services to the standard required by NSPs in order to meet their reliability obligations
Consequences if desirable capabilities are not achieved	If DER cannot effectively provide services to NSPs, there will be less options for NSPs procuring these services and could be corresponding detrimental impacts on energy prices for all consumers and returns earned by owners of DER due to: • Increased network costs, as networks are unable to access potential cheaper alternatives • Increased constraints on the export of energy from DER, which will increase wholesale energy prices for all consumers and reduce returns for DER owners