Australia is fast becoming a leader in the integration of distributed energy resources (DER) into the energy system. While positive, the uptake of these technologies, together with continued improvements, have outpaced the ability of distribution networks to manage subsequent grid impacts.

The challenges distribution network service providers (DNSPs) face can impact network infrastructure and household appliances. Without adequate alternative options, DNSPs are relying upon fixed export limits and planned infrastructure augmentation to manage these emerging challenges.

In February 2019, the Australian Renewable Energy Agency (ARENA) awarded $9.6 million to support the transition to an electricity network that is increasingly powered by DER.

Four projects (Jemena, SA Power Networks, Solar Analytics and Zeppelin Bend) are trialling new ways to maximise the amount of distributed energy that the network can accommodate, while maintaining the stability of the system. A further seven studies (Australian National University, CitiPower & Powercor, CSIRO, Dynamic Limits, Oakley Greenwood, University of Melbourne and University of Tasmania) are investigating how high penetrations of distributed energy can be successfully integrated into the energy market and grid.

This report summarises the progress made in year one of the initiative.

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AUSTRALIAN NATIONAL UNIVERSITY:
COMMUNITY MODELS FOR DEPLOYING AND OPERATING DER

ARENA FUNDING: $498,000
TOTAL PROJECT COST: $1.37 MILLION
LOCATIONS: AUSTRALIAN CAPITAL TERRITORY, QUEENSLAND, TASMANIA, VICTORIA

PROJECT SUMMARY
The increasing prevalence of behind-the-meter solar generation and battery storage is often motivated by high network tariffs, which discourage the transport of energy between generation, storage and load assets that are not co-located. This project is investigating community energy models, where distributed generation, storage and load are not co-located behind a single metered connection point. Through this work, the project aims to provide the basis for greater adoption and deployment of community energy models both in Australia and around the world.

YEAR ONE FINDINGS & NEXT STEPS
ANU’s social research has found that community energy groups strongly value local energy generation linked to local consumption - the term ‘energy sovereignty’ was used to capture this concept. Networks also appear willing to engage in local storage models; however, there are some challenges including current regulations. ANU’s simulations show that community energy storage (CES) may allow increased DER penetration, compared to residential storage.

For one scenario based on a combined group of 55 households, rooftop solar generation was increased up to 7kW per house, and CES reduced export power to the wider grid by 50 per cent compared to equivalently-sized residential storage. However, to fully access the benefits of CES a local use of service (LUOS) reduced energy transport tariff might be required to incentivise the local exchange of energy between customers and the storage asset.

The team will continue expanding their social science research and investigation into community energy models during 2020.

CITIPOWER & POWERCOR:
DISTRIBUTED ENERGY RESOURCES HOSTING CAPACITY STUDY

ARENA FUNDING: $164,000
TOTAL PROJECT COST: $353,000
LOCATION: VICTORIA

PROJECT SUMMARY
This project aims to demonstrate the issues faced by Australian distribution networks in maintaining security and quality of supply in the context of increasing penetrations of DER. The project will provide industry with a replicable methodology to assess both DER hosting capacity and the potential options to increase DER penetration. This methodology will use publicly available analysis tools in combination with smart-meter data at a 30-minute level, and other network, customer and weather data sets to assess limitations and the most cost-effective opportunities for increasing hosting capacity on the network.

The project will engage with CSIRO on their experience in the development of the network models published by in the medium-voltage National Feeder Taxonomy Study, and will also provide insights for their development of low voltage models to ensure consistency with the current CSIRO National Low Voltage Feeder Taxonomy Study. Once the methodology has been completed, CitiPower and Powercor will be able to identify and assess a broad range of customer and network level mitigation options currently available to distribution networks in some key growth areas of the network.

YEAR ONE FINDINGS & NEXT STEPS
During year one of the round, CitiPower and Powercor gathered and cleansed input sources, including 30-min smart meter data, network supervisory and operational data, to develop 10 low voltage (LV) network topologies comparable to LV networks across the CitiPower and Powercor networks. This was an increase from the originally proposed five topologies due to the greater range of customer types and supply areas covered by the network.

A methodology has been created to assess DER hosting capacity and value capacity increases against the costs of various remediation options, and five wider area network models have been developed to test and verify the representative LV network topologies against the real systems operation.

CitiPower and Powercor have been working with industry partners to develop a modelling approach to address limitations in the publicly available analysis tool. This primarily focused on the limitations in assessing unbalanced LV networks and single phase systems, as the tool is limited to assessment of balanced three phase systems at this time. Finally, CitiPower and Powercor are working on delivering hosting capacity assessment results, to a 30-minute resolution, for five key remediation options focused on the LV networks including both customer side or network side strategies.
CSIRO:
NATIONAL LOW VOLTAGE FEEDER TAXONOMY STUDY

ARENA FUNDING: $485,000
TOTAL PROJECT COST: $2.7 MILLION
LOCATION: NATIONAL

PROJECT SUMMARY
The CSIRO are developing the first nationally representative taxonomy of low-voltage (LV) networks. The aim is to describe and better understand the real-world characteristics of Australia's distribution systems, which will help with the design of innovative network management technologies that can contribute to the stability, reliability and performance of networks.

The study involves working with DNSP partners to gather and summarise key characteristics of Australian LV networks at a regional level, and then identify LV network types with common design and deployment characteristics. The National LV Feeder Taxonomy will provide users with a concise description of the technical characteristics of the identified network types, as well as their common application in the national distribution system. The final stage of the study is to integrate DER models (PV, battery energy storage systems, and demand response) into custom-built power-flow models unique to each LV network type.

YEAR ONE FINDINGS & NEXT STEPS
The CSIRO continues to work closely with DNSP partners via regular working groups and workshops to drive collaboration and knowledge sharing. Work continues on defining the data requirements and gathering data from the LV feeder networks across Australia. Common formats and tools have been identified from the LV feeder data, which will be used to develop the taxonomy.

DYNAMIC LIMITS:
DISTRIBUTED ENERGY RESOURCES FEASIBILITY STUDY

ARENA FUNDING: $292,000
TOTAL PROJECT COST: $798,000
LOCATIONS: NEW SOUTH WALES, SOUTH AUSTRALIA

PROJECT SUMMARY
Dynamic Limits is investigating the feasibility of applying principles of distributed control to create dynamic DER operating envelopes on radial feeders on distribution networks. The study consists of a general technical feasibility study, as well as two site-specific feasibility studies examining feeders with both rural and voltage constraints. The approach has the advantage of removing the need for network models used to calculate the point of constraint by measuring relevant constraints directly. This approach has the additional advantage of creating a more robust system that is both able to withstand a loss of communications and does not have a single point of failure.

YEAR ONE FINDINGS & NEXT STEPS
A general technical feasibility study has been conducted and indicated that through the implementation of the dynamic control scheme, DER hosting capacity can be increased by as much as six times without the need for network augmentation and only a minimal need for curtailment.

Several workshops were held in 2019 to discuss and uncover potential roadblocks for the implementation of the system and any critical tasks that any system needs to achieve. Site-specific studies are now underway, with data for an urban feeder currently being analysed.
JEMENA ELECTRICITY NETWORKS: DEMONSTRATION OF THREE DYNAMIC GRID-SIDE TECHNOLOGIES

ARENAs FUNDING: $1.12 MILLion
TOTAL PROJECT COST: $2.61 MILLion
LOCATION: VICTORIA

PROJECT SUMMARY
Jemena and project partners AusNet Services and University of NSW are demonstrating how increasing the visibility of LV networks can help manage grid power and voltage fluctuations. Three grid-based technologies are being assessed:

1. Dynamic phase switching of customer loads on LV feeders to help mitigate localised over-voltage challenges caused by concentrated DER assets
2. Dynamic power compensation to adjust the output voltage and mitigate load unbalance challenges at distribution transformers
3. Battery energy storage with Virtual Synchronous Generator (VSG) capability to mitigate potential power quality and network stability challenges caused by very high DER penetration.

YEAR ONE FINDINGS & NEXT STEPS
Jemena and its project partners have developed the equipment specifications and completed bench testing of the effect of phase shifting operation on common household appliances (e.g. the impact of momentary power loss across the switching cycle). Data has been collected from two demonstration networks to feed into network modelling. Computer modelling for optimal placement of the new network technologies and operating parameters has been completed. Jemena and AusNet Services have worked closely with local residents and councils and have successfully installed and begun field trials of pole-mounted phase shifting devices, a power compensation device and central controllers.

A containerised battery energy storage system (BESS) is scheduled to be installed by Jemena in early 2020, and Jemena will continue sharing progress of their project through roundtables, seminars, presentations and publications.

OAKLEY GREENWOOD: PRICING AND INTEGRATION OF DISTRIBUTED ENERGY RESOURCES

ARENAs FUNDING: $207,000
TOTAL PROJECT COST: $569,000
LOCATION: NEM-WIDE

PROJECT SUMMARY
Oakley Greenwood is investigating ways in which price signals can better reflect the value that DER services can provide to the electricity supply chain. The intention is that more cost-reflective price signals can incentivise stakeholders to make investments in DER in locations and at scales where it is most needed, and to deploy DER when and how it is of most value. This will maximise the value provided by DER assets through the provision of the correct price signals at all levels of the supply chain and the various levels of markets, thereby helping to:

(a) ensure that the electricity needs of all customers are met at the least total cost
(b) create opportunities for customers, industry and third-parties.

YEAR ONE FINDINGS & NEXT STEPS
The study has examined the regulatory and economic environment of DER, both in the National Electricity Market (NEM) and internationally. Oakley Greenwood have consulted widely with electricity retailers and distributors, relevant market bodies, consumer groups and intermediaries involved in delivering DER products and services to identify 10 areas in which DER can reduce costs in the central electricity supply system.

Alternative price structures – rather than a single prescribed pricing structure – were developed for each of these DER services in order to provide flexibility to distribution businesses and relevant wholesale market bodies in selecting pricing approaches that can provide the best balance of accuracy, complexity and administrative cost.

A cost-benefit assessment was conducted and indicates that the provision of these prices is likely to be highly cost-beneficial. Additionally, a review of the existing National Electricity Rules and regulatory framework of the NEM indicates that minor changes would be needed to implement these alternative pricing approaches.
SA POWER NETWORKS:
ADVANCED VPP GRID INTEGRATION

ARENA FUNDING: $1.03 MILLION
TOTAL PROJECT COST: $2.48 MILLION
LOCATION: SOUTH AUSTRALIA

PROJECT SUMMARY
The Advanced VPP Grid Integration Project aims to demonstrate how higher levels of energy exports from customers’ solar and battery systems could be enabled through the use of dynamic, rather than fixed, export limits, and to test the additional value this could create for customers and Virtual Power Plant (VPP) operators. To achieve this, SA Power Networks has implemented an interface (API) to exchange real-time and locational data on distribution network capacity between SA Power Networks and Tesla, enabling Tesla’s 1,000-customer SA VPP to increase its output when there is available network capacity. This concept is being tested in a field trial that commenced in July 2019.

YEAR ONE FINDINGS & NEXT STEPS
During the first year of the project, SAPN have established a DER integration API working group, which brings together several related ARENA projects to collaborate on API design and development, and a separate VPP technical reference group (now convened by AEMO). In collaboration with the API working group, SAPN have developed a distribution network API specification to support DER registration, monitoring and the publication of network constraints. The API has been integrated with Tesla’s VPP management and market trading systems, including global updates to Tesla’s Powerwall firmware to support the dynamic export limit function, and commenced live field trials in July 2019. The project is on track and SAPN are on target to complete the 12-month trial mid-2020.

SOLAR ANALYTICS:
ENHANCED RELIABILITY THROUGH SHORT-TIME RESOLUTION DATA

ARENA FUNDING: $491,000
TOTAL PROJECT COST: $1.28 MILLION
LOCATION: NEM-WIDE

PROJECT SUMMARY
Solar Analytics are working with AEMO and Wattwatchers to improve the monitoring capabilities of voltage disturbances, as well as automating short-time data capture triggered by grid events. This will allow for increased visibility, predictability and/or potential control of DER for AEMO, network service providers and other relevant entities, as well as provide a better understanding of the system security and reliability challenges caused by increasing DER penetration in certain areas across the grid.

One of the benefits of the project is to optimise power system operation within secure technical limits and enable the market operator to manage the power system with a high share of DER while maintaining reliability and system security.

YEAR ONE FINDINGS & NEXT STEPS
During the first year of the project, Solar Analytics provided several datasets to AEMO. Analysis of the high-resolution data enabled AEMO to identify specific behaviours of small-scale PV systems during frequency and voltage disturbances that are critical to predicting overall network response and preparing appropriate responses. AEMO is currently preparing public reports on these findings.

Wattwatchers have also delivered a firmware upgrade that enables the regular reporting of voltage statistics, which provides more useful information around such disturbances. Wattwatchers and Solar Analytics are currently working on rolling out these upgrades across the Solar Analytics fleet of over 20,000 monitoring devices.
UNIVERSITY OF MELBOURNE:
ADVANCED PLANNING OF PV-RICH DISTRIBUTION NETWORKS STUDY

ARENA FUNDING: $203,000
TOTAL PROJECT COST: $497,000
LOCATION: VICTORIA

PROJECT SUMMARY
The University of Melbourne study is a three-stage investigation to understand how DNSPs can make the most of their networks to accommodate residential solar PV. The study starts with the development of detailed full three-phase integrated HV-LV network models to quantify the impacts of various solar PV penetrations on network performance. Then, using these models, the University will explore how to quickly estimate PV hosting capacity without the need for complex and detailed network studies.

The aim is to develop innovative analytical techniques to assess network hosting capacity of solar PV by using readily available HV network and customer (smart meter) data. Finally, The University of Melbourne will investigate planning options to assist DNSPs in increasing network hosting capacity.

Recommendations for DNSPs will be drawn from a techno-economic assessment of traditional solutions (e.g. network augmentation and existing voltage regulation devices) and non-traditional solutions (e.g. new voltage regulation devices, PV inverter capabilities, and battery storage systems).

YEAR ONE FINDINGS & NEXT STEPS
The first two stages of the study were successfully completed during 2019 and the corresponding reports made available to the public. Stage one involved the HV-LV modelling of HV feeders selected in collaboration with AusNet Services. Detailed three-phase network models from the head of the HV feeder down to the connection points of residential customers were produced for four significantly different HV feeders (long/short rural and long/short urban), each supplying electricity to 3000 to 5000 customers.

In stage two, an innovative analytical technique was defined to calculate the solar PV hosting capacity of a residential area (LV customers connected to the same distribution transformer). Using the developed detailed network models, growing PV penetrations in a horizon of five years were simulated to create a large realistic smart meter data set. The analytical technique was then applied to this data and tested for different PV penetrations. The findings show that the proposed analytical technique provides adequate estimations of PV hosting capacity, making it possible for DNSPs to have a faster and simpler alternative to time-consuming approaches that require full network models.

UNIVERSITY OF TASMANIA:
OPTIMAL DER SCHEDULING FOR FREQUENCY STABILITY

ARENA FUNDING: $527,000
TOTAL PROJECT COST: $1.18 MILLION
LOCATION: TASMANIA

PROJECT SUMMARY
The University of Tasmania aims to demonstrate via detailed modelling the frequency response capabilities of a range of inverter-interfaced DER and flexible loads, and the extent to which they can assist with frequency stability in power systems with decreasing conventional generation. The project will also develop optimisation software that enables fleets of DER in distribution networks to be operated so that this frequency response can be enabled while simultaneously respecting the physical constraints and limitations of distribution networks. Finally, the project will establish methods for and thus provide insights into how fleets of aggregated DER might actively participate in energy and FCAS markets in Australia so as to allow their frequency response capabilities to be harnessed in future.

YEAR ONE FINDINGS & NEXT STEPS
During the first year of the project, the team developed detailed models of inverter power electronics control for a number of DER types – photovoltaic systems, battery systems, electric vehicle chargers, inverter-based heat pumps (for space heating and cooling and for hot water heating) and inverter-based resistive loads (for hot water systems). These models were included in simple power system frequency response time-domain simulations, and operated alongside different types of conventional synchronous generators.

The models demonstrated the capability to provide fast responses with less frequency deviation and smaller settling time, particularly in power systems with decreasing levels of physical inertia. The team continues to develop models to demonstrate the value of this DER frequency responses in NEM power system frequency response simulations with a range of different generation mix scenarios, including with pumped hydro energy storage capacity. They have also assessed some of the conditions for, and capability...
Inverter-based DER alongside flexible loads to still provide adequate frequency response when exposed to network fault conditions.

The project team is also developing network-constrained bidding optimisation strategies to support and coordinate the participation of aggregators of DER in the electricity (wholesale energy and frequency reserve) markets. The approach consists of a decentralised optimisation approach, where aggregators negotiate with distribution system operators (DSOs) to define network-constrained energy and reserve bids. The optimisation method breaks down the network-constrained bidding optimisation problem into aggregators and DSO problems.

Multiple aggregators are able to operate in the same distribution network, with each aggregator optimising the flexibility of its fleet of DER, and with the flexibility at the same time ‘aggregated’ at the distribution network MV substation level. This optimisation software has been implemented and tested but is undergoing further development.

In order to demonstrate possible integration of such an approach into NEM energy and reserve markets, a simplified dispatch engine (NEMDE equivalent) has been built and tested for energy bids and is being extended to incorporate reserve bids and thus DER aggregator dispatch.

ARENA FUNDING: $4.29 MILLION
TOTAL PROJECT COST: $12.94 MILLION
LOCATIONS: AUSTRALIAN CAPITAL TERRITORY, NEW SOUTH WALES AND QUEENSLAND

PROJECT SUMMARY
The Zeppelin Bend (Zepben) project is developing mechanisms to orchestrate the operation of DER assets by continuously providing ‘operating envelopes’ to the DER via integration with aggregator systems. The project includes integrating Zepben’s existing Energy Workbench platform with DNSP partner systems to obtain medium- and low-voltage network models and measurement data that will be used as inputs into the algorithms to calculate the operating envelopes. Such operating envelopes will ensure that the secure technical limits of electricity distribution networks are not breached, and will allow for greater integration of DER assets into the grid.

YEAR ONE FINDINGS & NEXT STEPS
The project has made considerable progress in the first year. A common information model (CIM) standard based data platform (designed to marshal network asset models and data) has been developed and made available via open source:
https://bitbucket.org/account/user/zepben/projects/OS
https://zepben.bitbucket.io/docs/cim/zepben/

The initial versions of agents that will integrate with DNSP systems have been completed and are pending deployment within a DNSP partner’s IT infrastructure. An AZURE-hosted instance of the evolve data platform, including associated authentication and security mechanisms, has been created and penetration testing for cyber security assurance is underway. Zepben’s principle project partner, the ANU, is building the aggregator-facing API that will be used to register DER assets with the evolve platform, as well as designing the operating envelope engine. The first end-to-end testing is scheduled for July 2020.