Solar Forecasting for Low Voltage Network Operators

SEPTEMBER 2018

Oakley Greenwood

Developed by Oakley Greenwood on behalf of ARENA

Australian Government
Australian Renewable Energy Agency

ARENA

DISCLAIMER

This case study has been prepared at the request of the Australian Renewable Energy Agency (ARENA). It is intended solely to provide information on a project that has received funding from ARENA.

The information provided in this case study is derived in large part from information provided by a range of parties other than Oakley Greenwood (OGW). OGW explicitly disclaims liability for any errors or omissions in that information, or any other aspect of the validity of that information. We also disclaim liability for the use of any information in this report by any party for any purpose other than the intended purpose.

DOCUMENT INFORMATION

Project	PV Forecasting for DNSPs
Client	ARENA
Status	Project Overview
Report prepared by	Rohan Jones (rjones@oakleygreenwood.com.au)
Date	20 September 2018

TABLE OF CONTENTS

TABLE OF FIGURES

1 INTRODUCTION

Australia leads the world in the uptake of rooftop solar (PV). As the proportion of energy from PV increases, a point is reached where the natural fluctuation of the output, due to both intermittent and sustained cloud cover, can cause problems on the local distribution network that the PV is connected to.

Most rooftop PV installations in Australia are connected to the site on the load side of the electricity meter, and are 'net metered'. Under net metering only the net amount of electricity exported to the grid is measured; the amount of energy produced by the PV system is not measured.

The Australian National University (ANU) with support from the Australian Renewable Energy Agency (ARENA) and involvement of most of Australia's electricity distribution network service providers (DNSPs), have deployed an operational framework for the prediction of power output from solar PV, which groups total power generation according to low voltage network assets (e.g. zone substations) (the project). This operational framework combines solar PV installation data (locations, capacities), along with electrical network information (which zone substation or feeder line the PV site is connected to) that is provided by the DNSP partners, to make near-term predictions of the power output from those PV systems.

Forecasts are created by operational solar forecasting systems developed and maintained by commercial entity Solcast (Solar & Storage Modelling Pty Ltd). Solcast is a partner in the ANU project and has been engaged to provide global coverage of rapid update solar forecasting technologies, which detect, track and predict the future positions of cloud cover through the use of weather satellites and numerical weather models. In the Australian region, services for cloud cover imagery are provided by the Himawari 8 satellite. Solcast provides forecasts of PV power output through solar radiation forecasts produced by these operational systems, which are converted to power output predictions via proprietary PV modelling algorithms.

This paper provides an overview of the project including a review of the challenges that high penetration levels of PV can pose to DNSPs' planning and operations, the components and outputs of the ANU project as well as how it can assist DNSPs to better understand, address and manage these issues, including how doing so can assist a DNSP to integrate higher levels of PV penetration and export. The rest of this paper addresses the following topics:

- the challenges associated with highly saturated PV parts of the network including where DNSPs do not have real time monitoring of the low voltage networks
- what information DNSPs require to accept high-penetrations of distributed solar PV
- how distributed solar forecasts and simulations can be usefully delivered to DNSPs
- the benefits of high-precision solar forecasting technology for high-penetration solar integration
- the solutions DNSPs currently use to accommodate high-penetration of distributed solar PV and
- how this project relates to the future controls landscape of the smart grid.

2 PV AND THE ELECTRICITY GRID

2.1 The electricity grid

The electricity grid consists of two components, the transmission network and the distribution network. The transmission network transports the electricity produced in large generating plants at high voltage levels to load centres in cities and large rural towns. The transmission grid is heavily interconnected and, in many circumstances, supports power flows in different directions. Only a few very large customers (large industrial customers such as smelters) are connected to the transmission network.

The distribution network takes power from the transmission network at terminal stations that are located around the major cities and rural centres. The distribution system reduces the voltage of the electricity to levels suitable for use in industrial and commercial facilities and small businesses and households. Almost all customers are supplied through the distribution network, and only a relatively small number of customers, such as large factories, are connected to higher voltage levels within the distribution network. Most customers – and virtually all residential customers – are connected to the low voltage part of the distribution network.

The Distribution Network has a number of functions, including to:

- transport power from the transmission network to customers
- reduce the voltage of the power to levels that are suitable for the customer's use
- instantaneously match supply and aggregate demand at a local level
- ensure that the voltage in the low voltage portion of the network is maintained within a specified range at the customer's point of supply
- ensure that the reliability of supply to customers is maintained above specified levels
- ensure that the quality of supply (including factors such as transient and short-term voltage fluctuation or flicker, harmonics, dips and sags in voltage, etc) are kept within specified levels and
- ensure that the electricity network is safe and does not pose a danger to the public.

At the low voltage level, it is common for there to be no remote monitoring, remote operation or automated operation (other than simple fuses). Remote monitoring and operation of the low voltage system has not been necessary because:

- information on the number and type of customers and the application of standard 'load profiles' for each customer type provided sufficient knowledge of the load on each feeder
- fuses were sufficient and effective as the standard form of protection at the voltages within the low voltage network
- customers can be relied upon to report any outages that occur and
- an outage on a low voltage feeder (or even a distribution substation) only affects a relatively small number of customers.

The vast majority of PV (and all the installations that are the subject of this report) are connected to the grid at the low voltage level.

The distribution network has been designed as a radial system and operates on the basis that power always flows in the one direction, and always from a higher voltage to a lower voltage at a substation. This design followed from the fact that electricity generation has historically exhibited strong economies of scale. This meant that the cheapest way to generate electricity was in large plants. Delivery of the electricity to end users then required a network, but because all generation came from large plants, the network only needed to accommodate electricity flow in one direction. These factors have shaped the design of the networks, including:

- in general, line capacity is lower and conductor sizes are smaller in the downstream portions of high and low voltage feeders than in the upstream portions and
- protection on the distribution network generally only operates for faults that are downstream of the protection device; at low voltage, protection is generally provided by fuses.

However, increased deployment of distributed energy resources (DER) – particularly the rapid increase in the installation and use of rooftop PV systems - has meant that it cannot be assumed that the grid will always operate in a unidirectional manner.

The fact that (a) the output of a PV system is dependent on the strength of the sunlight available (which changes from season to season, from day to day and in some cases within the hour of a day) and (b) the amount of PV-generated electricity that is exported to the grid is also dependent on the amount of electricity being consumed within the facility at the time (particularly in the absence of some form of energy storage) makes it difficult for a DNSP or a market operator to forecast the amount of electricity likely to be needed from the grid.

Other aspects of how DER and PV systems operate pose additional factors that can affect the operation of the network. The following section describes the additional matters that a DNSP must consider when high levels of rooftop PV penetration are reached.

2.2 Effects of high levels of PV penetration on the grid

PV is installed and connected behind the customer's meter and is connected, via the customer's connection to the low voltage network. The energy produced from a PV is initially consumed on site and, at this stage, has minimal effect on the grid. If the power supplied by the PV exceeds what is required on site, the excess is put back into the low voltage network. At lower levels of PV penetration in an area, this is normally not a problem because the exported power is consumed by neighbouring loads and, although reduced, the power supplied by the grid is still sufficient to provide voltage stability.

However, as the number of PV systems increases, and the power generated from PVs in a particular area gets close to, or exceeds, the total load in that area at any point in time, the PV generation can cause problems on the local grid.

The problems that can be caused by high levels of penetration of PV systems include:

- reduced understanding of the native load and its interaction with PV because of the lack of visibility of PV generation
- voltage fluctuations due to short term fluctuation in PV generation
- increased wear and tear on transformer tap changers
- spurious tripping of protection devices and
- voltage rises and changes to the voltage profile of the feeder.

The ANU project is seeking to address two of these issues:

- the lack of visibility of PV generation and
- voltage fluctuations due to short-term fluctuations in PV generation.

2.2.1 Lack of visibility of PV generation

The net metering that is generally used for rooftop PV systems does not allow the energy produced by the PV to be directly measured. Rather, the amount exported to the grid is measured – which occurs when the energy consumed on site is less than the energy produced by the PV. Consequently, DNSPs do not know how much electricity was generated by PV systems within their network in the past, how much those systems are currently generating, or how much they are likely to generation – and when they are likely to generate it – in the future. This lack of visibility and consequent lack of information complicates and reduces the accuracy of the load flow modelling and other considerations that go into the DNSP's forecasting and planning.

The ANU project attempts to address this issue by using the Solcast forecasting and PV modelling systems to generate estimates of the PV power output every 10 minutes. These are produced by mapping the capacity of the PV systems installed and other aspects of the connection of each PV installation to the LV network to the local cloud cover conditions (whether historical, real-time or forecast). This information can be used as historical data to inform load flow analysis for network planning purposes.

In short, high penetration of PV on a feeder can hide or mask the actual, or 'native', load on the feeder. With PV operating and supplying much of the load on the feeder, the demand required to be supplied by the grid will be lower than the aggregate of the customer load on the feeder. In this situation, it is possible that the DB may be unaware of the native load on the feeder, and not be able to ensure that the capacity of the network is sufficient to meet total aggregate demand. In situations of extreme and extensive cloud conditions, where there is little or no PV generation, all of the load will need to be supplied from the grid. In these circumstances there is a risk that the feeder will be overloaded, and an outage may occur.

2.2.2 Short term fluctuation in PV generation

As clouds shade PV systems, their power generation is reduced proportionately to the opacity (i.e. how much light gets through) of those clouds. Where there is a large number of small moving clouds (i.e. broken cloud cover), this causes the generation from the PV to fluctuate. In small geographic areas with high penetration of PV systems, individual clouds may affect a large number of PV systems at the same time, thereby amplifying the level of fluctuation in PV output and demand that needs to be met from the grid.

Rapidly-transitioning cloud cover conditions result in voltage fluctuations into the grid as the collective power output of PV ramps up and down. This has an impact on the network and the energy market. Given the lack of visibility and poor ability to predict aggregated power ramping events, DNSPs can only manage these fluctuations in grid voltage reactively. The ANU project is seeking to provide short-term forecasts ('nowcasts') via the Solcast operational systems, and work with DNSPs to identify solar induced voltage fluctuations and plan strategies for their mitigation. At present, the DNSPs do not have the tools that are required to plan or to execute the necessary response (and are unlikely to obtain these tools in the foreseeable future). As a result, while the ANU project may be able to inform the DNSPs that unacceptable voltage fluctuations may be occurring, there is little that the DNSPs can do at present to mitigate these conditions.

3 INFORMATION REQUIRED BY DNSPS TO MANAGE HIGH PENETRATION OF PV

The low voltage network of a distribution system is generally passive. Unlike the higher voltage networks, there are very few remotely controllable components on the LV network and even less automation. Beyond a certain level of PV penetration in a local area, the LV network is not able to operate within its required levels of reliability. Information alone is not sufficient to support the further penetration of PV.

When a customer applies to install PV generation they are required to provide the distributor with technical information about the PV cells, the inverter and where the system is to be connected (both geographically and in relation to its connectivity). This includes the cumulative rating of the PV cells, the output rating of the inverter and other technical information. While this information is necessary for the DNSP to know what is connected to its network, it is not sufficient to allow a higher penetration of PV than the network is inherent capable of supporting on a passive operational level. Fundamentally, the management of the low voltage network and, consequently, the management of the effects of PV, is currently reactive.

To analyse the cause of identified problems on the network and to plan for the development of the network to meet future demands, DNSPs conduct load flow studies. Prior to the significant penetration of PV, studies assumed that energy only flowed in one direction and all the energy required to meet customer load was supplied from the upstream grid. On this basis, the information required for load flow studies included only:

- the capacity and connectivity of the elements of the network
- current levels of demand and
- forecasts of demand and customer growth.

The penetration of PV has meant that the assumptions of unidirectional energy flow and the supplying of all load from the grid is no longer valid. In order to accurately model load flow on the network in an environment of PV penetration, the amount and timing of energy provided by PV also needs to be considered.

As noted earlier, historical data on actual PV generation over time is not available (i.e., the lack of PV visibility). As a result, DNSPs are required to make a range of assumptions about PV generation and its effect on the network. The data provided to the DNSPs via this ANU-led project will accumulate into a historical database when gathered by the DNSPs, and should provide material improvement on these assumptions and significantly improve network loadflow studies.

4 THE ANU PROJECT AND WHAT IT PROVIDES TO DNSPS

The ANU, supported by ARENA and the active involvement of 12 of the 15 electricity distribution businesses in Australia, is developing and refining techniques for predicting real-time and future electricity generation from distributed PV at a relatively small geographic level.

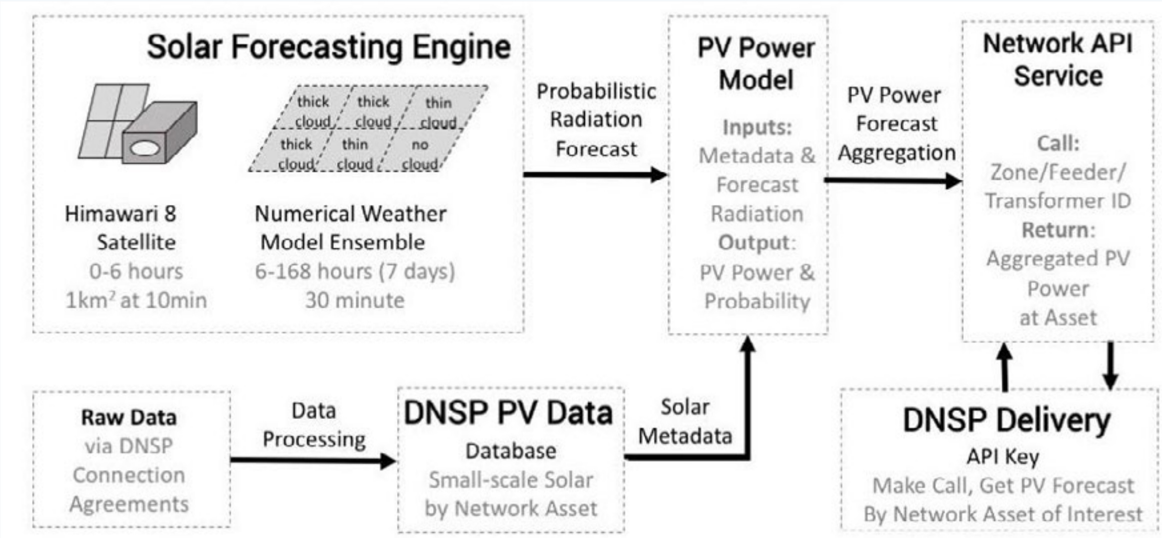
The project is comprised of the following components.

- Solar Forecasting services provided by Solcast which utilise advanced satellite weather mapping at 1km resolution updated every 10 minutes and provide a 0 to 7-day probabilistic forecast of radiation in 30-minute resolution (available at up to 5-minute resolution)
- Raw data on the capacity of rooftop PV systems connected at the distribution system asset level as provided by DNSPs and organised into databases by the ANU

- A PV Power Model (Solcast) that combines the information from the two components above into a probabilistic forecast of PV output at the distribution system asset level and
- An Application Programming Interface (API, Solcast) that allows the DNSP to call for and receive those forecasts at the distribution system asset level.

The project also includes an effort to move the information and capabilities that are being developed from academia to the industry as quickly as possible. Intellectual Property generated within the project is intended to be commercialised by Solcast. Figure 1 below shows the organisation and interaction of the components that provide these capabilities.

Figure 1: ANU project, including Solcast components and DNSP provided outputs



Source: ANU

The project is also integrating information being made available from Fronius on the real-time performance of thousands of actual PV systems. This information will allow the project to fine-tune its forecasts, and improve them by taking into account information on the impact of variables like shading, and the tilt and orientation of the PV arrays.

In total, the system provides significant benefits in improving the visibility of the PV generation within the distribution network at a very localised level, including the relationship between weather variables (irradiance, cloud cover and opacity), PV capacity and other installation characteristics, PV output and operational parameters of the distribution network.

At present, the system provides information at the zone substation level, but resolution can be increased to finer scales. Current pilot projects include feeder level modelling, and forecasting for virtual power plants.

This information provided by ANU and Solcast can be useful to DNSPs in two ways, as discussed in the following sections. Further, there appears to be opportunities for the AEMO, in its role as the system operator, to benefit from this information as well it being useful to support medium term forecasts of power availability from large-scale solar generators. These are also discussed below.

4.1 Improved visibility to improve DNSP load flow modelling and system planning

DNSPs conduct load flow studies on their network to understand the demands on all the elements within their networks. This allows them to determine where there is potential for overload under various conditions including seasons of the year, time of day and outage conditions. These analyses use forecasts of demand based on historical actual demand and known or expected growth.

However, as discussed earlier, there is a lack of past, current and future PV power generation visibility in the LV grid, which is affecting the accuracy of DNSPs' load flow modelling and forecasting. The data from the ANU project will significantly improve DNSPs' ability to accurately model the demands on their networks and to determine capacity requirements, taking into account the amount of PV present and its output at the local level.

Assuming that the data being made available comes in a form that the DNSPs can incorporate into their systems, the ANU project data for load flow modelling can be used by and benefit the DNSPs immediately. Other than data integration or migration, there does not appear to be any barriers to the DNSPs utilising this data to significantly improve their understanding of the operation of their networks.

In circumstances where LV data is available or able to be captured, such as in Victoria where Advanced Metering Infrastructure (AMI, or smart metering) is present, this analysis may also be able to be done on an on-going basis, making regular provision of the ANU data valuable.

4.2 Improved visibility to provide better information about and response to transient cloud cover

Responding to transient fluctuations in load and demand requires two key elements: knowledge that the event is likely to occur prior to its occurrence; and the ability to take action to respond. The ANU forecasts provide the first element by giving DNSPs the knowledge that a fluctuation in PV generation of a certain magnitude is likely to occur at a future point in time. However, at present, the DNSPs lack the ability to proactively respond. Significant investment, as well as some changes in regulations and customer attitudes are likely to also be required. Until these investments and associated changes in regulation and customer attitudes are made the value of forecasts of fluctuations of PV generation due to transient cloud cover is likely to be of minimal value to the DNSPs at the operational level. While work has been done on standards to allow communication with network and customer devices, the implementation of remote operation and automations is still a number of years off.

In a scenario where this investment has occurred on remotely controllable and automated network components and, in particular, where the DNSP has control of storage and/or load, the ANU data in real time will be of significant benefit. In real time, as transient cloud cover is identified and the effect on PV generation is predicted, the DB will be able to respond to reduce the effects of the variation in PV output on grid voltage. In this case the ANU data will need to be in a format that the DNSPs' SCADA and Network Management systems can use directly.

Integration of solar forecasting technologies with the operation of the LV grids could enable the offset of ramping events and other challenges such as reverse load flow or network wear and tear, through the orchestration of demand-side management, energy storage and smart inverter technologies. While this potentially could require a significant amount of data being available and processed in a short period of time, not all parts of a given DNSP's network will be subject to high penetrations of PV at the same time and potentially require intervention. The distributor should be able to pre-define the areas of concern and for which they require this information. Further, if data volumes and speed of communication remains an issue, it may be possible for the data to be filtered before providing it to the DNSP. For example, the DNSP may be able to pre-set an acceptable range so that information is only provided where the predicted PV generation for a substation (or other network element) is outside that range.

4.3 Short-term forecasting for the system operator

At the transmission level, where the system operator must ensure that there is sufficient capacity dispatched to match aggregate demand, accurate and reliable forecasts of PV generation would be of significant benefit. Regular and accurate forecasts from the ANU model, rolled up to terminal station level, would provide the system operator with robust information on how much load will be met by PV generation in the distribution network and, therefore, how much load needs to be met by centrally dispatched generation.

4.4 Large-scale solar generators

Solcast technologies are also capable of forecasting energy output from large-scale solar generators. In fact, it would be expected that the forecasts of output from a large-scale solar generator would be more accurate than for distributed PV. Many of the factors that are uncontrollable or unknown in distributed PV, such as tilt and azimuth of the solar panels, the amount of dust and dirt on the panels, shading from trees and other structures, etc, are known and controlled in the more actively managed environment of a large-scale solar farm.

Solcast is already working with a number of large Australian solar farms for forecasts from as little as five-minutes ahead to several hours ahead . The immediately available output from such an installation is already know as it is directly metered. In the longer term, issues such as transient cloud cover are less relevant than total capacity, the time of the year, sunrise and sunset times and maintenance schedules.

5 CURRENT OPTIONS FOR MANAGING IMPACTS OF HIGH PV PENETRATION

The tools currently available to DNSPs for managing the effects of high penetration of PVs are relatively limited. While traditional network investment options are available, it has become more difficult to justify these types of expenditure. The ANU data may be able to strengthen the case for network capital investment to allow PV generation at the LV level of the network to be more actively managed, leading to greater levels of orchestration and contribution of these resources.

DNSPs, and the industry more broadly, are currently using or investigating the following approaches to manage (or avoid) instances of high penetration of PV.

- Uprating feeders and substations – the uprating of feeders and distribution substations will increase the capacity of the network to accept higher levels of PV generation and may also act to reduce voltage drop.
- Line drop compensation – the installation of line drop compensators (LDC) mid-way along a feeder will assist in reducing high voltages. With an LDC, the voltage at the distribution transformer can be set at a lower level, allowing more ‘headroom’ for voltage increases between the substation and the LDC. The LDC will then raise voltage for customers further down the feeder. LDC can also manage high voltages at the end of the feeder due to PV installations.
- Capacity limits – most DNSPs apply capacity limits on the size of a PV system that can be connected (generally 5kW or 10kW for single phase installations and 30kW for three-phase installations). In some cases, this limit is applied to the solar panels, in others to the inverter output. Generally, applications for solar installations that are within these limits (and that meet all other technical requirements) will be approved. Applications for larger installations are treated on a case-by-case basis.
- Export limits – in addition to the capacity limits, some DNSPs also apply limits to the amount of power than can be exported to the grid, which will be less than the capacity limit.
- Static synchronous compensators – these are devices that automatically and passively provide voltage regulation and voltage stability within the local area of the LV network on which they are installed.
- Reduction of the network reference voltage – In accordance with AS4777.2 (*Grid connection of energy systems via inverters requirements*) inverters connected to the LV network must trip when the grid voltage gets to a set level, nominally 255V. This results in inverters indiscriminately tripping off the network when the volts are high. High voltage in this case is most likely to occur in situations of high PV penetration. In these situations, indiscriminate tripping of PV will cause voltage fluctuations on the network as well as frustration for customers whose PV systems are prevented from operating when capable of doing so, thereby not providing the benefits and return that was expected from those systems. One way of addressing this issue and reducing the likelihood of PVs tripping due to over voltage is to reduce the nominal voltage of the grid while still remaining within statutory requirements.
- Direct control – although not implemented at this point in time, this is where the DNSP would have control of a customer’s PV as well as the customer’s energy storage. This would allow the DNSP (or a third party responding to price signals from the DNSP) to manage the variability of PV output to the grid. This process could also involve grid-connected storage and controlled loads such as water heating. This is discussed further in the next section.

5.1 Current ARENA supported projects

ARENA is supporting several other projects that are also developing innovative tools and techniques for the better management of high PV penetration by DNSPs and to support higher penetration of PVs.

5.1.1 NOJA Power Intelligent Switchgear

This project aims to reduce the complexity and cost of connecting renewables to the grid and increase the hosting capacity of distribution networks by developing, demonstrating and industrialising an economical intelligent switchgear. This device can capture high-resolution real-time network data and can provide protection, control, and monitoring solutions to facilitate the connection of renewables to the grid.

This project will develop a range of switchgear products combined with unique controllers specifically targeting the requirements of DNSPs and reducing the connection cost of renewable energy resources. These products will manage the protection challenges associated with renewable resources integration and will increase the hosting capacity of the electricity network by using dynamic protection configuration, precise wide-area measurements and real-time monitoring capabilities. This will be achieved with advanced protection schemes and with GPS time synchronised phasor measurements (synchrophasors).

(reference: https://arena.gov.au/projects/noja-power-intelligent-switchgear/)

5.1.2 Increasing Visibility of Distribution Networks to Maximise PV Penetration Levels

This project aims to support electricity distribution companies to take a less conservative approach in assessing and approving additional customer PV systems to be connected to their networks. This is achieved by providing them with a better understanding of the operational conditions of their networks through the application of a proven state estimation technique (SEA) that generates an estimate of the network's operational conditions. These estimated results will form part of a network analysis tool through which the likely impact of the additional PV systems can be assessed.

The project will advance the existing and proven SEA technology from a proven prototype demonstration to a semi-automated system completed and qualified through tests and demonstration on feeders in the partner DNSPs networks.

(reference: https://arena.gov.au/projects/increasing-visibility-of-distribution-networks/)

5.1.3 Networks Renewed

This project seeks to increase the amount of renewable energy in Australia by paving the way for small-scale solar PV and battery storage installations to improve the quality and reliability of electricity on our national distribution networks. With a focus on voltage management, Networks Renewed is showing that residential solar can make a significantly positive impact on power quality, and that this makes commercial sense for both customers and electricity networks.

Networks Renewed is pioneering an innovative use of mass distributed solar and storage in Australia. The Institute for Sustainable Futures at UTS is partnering with electricity network businesses Essential Energy in New South Wales (NSW) and AusNet Services in Victoria, start-up company Reposit Power, the Australian Photovoltaic Institute, and the NSW and Victorian Governments to deploy trials, share the knowledge generated, and bring the idea of a truly smart electricity grid closer to a reality.

To achieve its goals, the project is tapping into 'smart' inverter technologies, the devices that connect solar and batteries to the network. Smart inverters have the capability to control how PV panels and storage interact with the grid, offering a suite of new business opportunities.

The project is comprehensively examining the technical alternatives for providing network support using smart inverters and building the business case that will make them commercially viable to networks, aggregators, and customers.

Industry partners have built practical, market-scale demonstrations in both NSW and Victoria to show that smart inverter technologies are a viable commercial option for providing network support services. The demonstrations are large enough to achieve meaningful improvements to power quality, verifying the effectiveness and value of voltage regulation services from smart inverters, in readiness to stimulate future projects and become normal operating practice for Australian distribution networks.

(reference: https://arena.gov.au/projects/networks-renewed/)

5.2 International experience

The issue of high penetration of PV is not unique to Australia. Other countries, such as Germany, have been confronted with issues caused by the high penetration of PV as well. The actions taken by DNSPs in Germany are listed below (source: B. Bayer et al. / Renewable Energy 119 (2018), 129e141).

- replacing local distribution transformers for higher-rated transformers
- segmenting the local grid and installing a new distribution substation
- laying parallel cables in the first sections of a feeder
- increasing conductor size to increase the capacity and reduce voltage drop
- installing voltage regulators and LDCs
- installing voltage-regulated distribution transformers adjusting the fixed tap on existing distribution transformers
- adjusting the voltage level at the zone substation
- providing reactive power compensation to improve power factor and
- changing the grid topology – moving the 'open points' on the HV and LV network to better 'spread' PV generation across feeders.

6 USING CLOUD PREDICTIONS TO MANAGE HIGH PV PENETRATION USING SMART GRID TECHNOLOGIES

The vision of Smart Grid is that devices on the network and within customers' facilities will be capable of operating together in an 'orchestrated' manner to achieve required outcomes. In the case of PV, this orchestration would address many of the issues of high penetration of PV and, ultimately, support greater PV generation. In the case of addressing fluctuations due to transient cloud cover, cloud forecasting and PV generation modelling, such as provided by Solcast to the ANU project, would play a critical part.

Solcast data can provide predictions of the level of PV generation in small geographic areas in real time. From this information, along with forecasts of the underlying customer load and knowledge of the characteristics of the network, systems will be able to determine if action is required.

If the level of PV generation is high and at a level that risks unacceptable voltage variation and reliability of the grid, a Smart Grid would be able to trigger local storage facilities, whether located at the grid or customer side of the meter, to act as a load and start storing energy. The Smart Grid could also turn on controllable loads, such as storage hot water, in order to utilise excess PV generation.

Conversely, if the level of PV generation is low, resulting in high demand on the grid, the Smart Grid could trigger the same local storage to provide additional supply into the area and ensure that all controlled loads are turned off.

In the morning, as PV generation ramps up and the demands on the grid ramps down, the Smart Grid could start charging local storage to reduce the gradient of the ramp. Such storage would likely need charging as it would have been utilised during the night to provide power when PV was not available.

Conversely, the Smart Grid would start discharging local storage as the evening PV ramp-down occurs and grid supply ramps up, so as to reduce the gradient of the ramp. Storage could continue to support the grid during the night, depending on the load, the level of energy stored and forecast availability of sunshine on the following day for re-charge of the storage.

When transient cloud and consequent fluctuations in PV generation are predicted, the Smart Grid could bring on line network devices such as static synchronous compensators and capacitor banks to smooth the fluctuations as well as local storage to support grid voltage as required.

7 SUMMARY AND CONCLUSIONS

The ANU project, in partnership with Solcast, has demonstrated an ability to forecast PV generation within a small geographic area with a high level of accuracy, even when influenced by transient cloud cover. The modelling uses satellite imaging of clouds from the Himawari 8 Satellite and details from the DNSP on the size, location and connectivity of rooftop PV. Using its forecast of solar radiation and its PV Power Model, the project produces forecasts of PV generation.

In the immediate future, this information will be useful to DNSP load flow studies. Net metering is used in all sites where PV is installed. This means that only the net energy imported or exported at the site is measured rather than the customer's full load and PV generation separately. The power generated from PV systems is not visible. However, PV generation is an important input to DNSPs' load flow studies where PV generation is present. This is particularly important where the penetration of PV is high. Currently, distributors use a range of assumptions in lieu of this data. The ANU project will be able to provide the necessary information on the level and timing of historical PV generation, greatly assisting DNSPs' load flow studies.

Solcast technologies are able to forecast near-term fluctuations in PV generation resulting from transient cloud cover. While this information may be of interest to DNSPs they currently lack the ability to proactively respond. In the future, as communications between devices is developed and the DNSPs gain the ability to control customer and grid storage, smart inverters and demand management, it may be possible to respond to information of forthcoming voltage fluctuations due to the effect of transient cloud cover on PV generation. However, there are many hurdles to jump and a scenario where this sort of proactive response is possible is still some way in the future.

In the meantime, DNSPs are reactively responding to the effects of high PV penetration in a number of ways including uprating the network where required, placing limitations on the size of installation or the level of energy that can be exported, installing synchronous compensators and line drop compensation, and reducing the grid reference voltage. There are also a number of ARENA supported projects investigating and developing tools and techniques for the DNSP to better manage high PV penetration.

Forecasts from the Solcast models, when combined with DNSP level data from the ANU project, may also benefit the system operator. The connectivity built into the ANU data will allow PV generation forecasts to be aggregated to terminal stations. Having more complete and accurate forecasts of the load that will be met by PV generation within the distribution networks will support increased certainty about the amount of dispatchable generation that will be required to supply the remaining load.

Solcast is already working with large scale solar farm generators for short-term (minutes ahead) to medium-term (hours ahead) forecasts of their energy. This may provide more certainty as to the contribution that these plants will make to the energy mix of the grid in the period of five-minutes to 24 hours into the future.