Paving the way for trouble-free 100% on-grid solar for housing projects

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Lachlan Bateman, Head of Power Systems Planning, Asia Pacific Energy Systems at DNV, discusses how, with some minor modifications to the 'standard' electrical distribution design approach for residential developments, networks may be able to accept high volumes of solar power within distribution code limits.

Multiple stakeholders in grid-connected, community solar residential projects need assurance that the electrical distribution design will comply with network codes and avoid disruption to grids.

Solar developers and investors, power grid companies, and regulators need to know there will not be adverse network impacts from having more solar PV installed than the normal allowable penetration for residential solar.

Typically, the recommendation in residential areas is to have a maximum of one third of households with a solar rooftop, to comfortably manage the impact of power flows from the solar units. Among the main concerns about exceeding this are that distribution voltages could be pushed beyond distribution code limits and network components such as transformers could be overloaded.

It is worth noting that exceeding the limit also creates potential for power quality, or harmonic issues, as the capacity of inverters on the network increases. However, mitigating measures to avoid this are usually only required for larger capacity systems than the example described below.

Enabling 100% solar residential developments

Consider this case study for a planned 8,000 resident community in Australia that illustrates how expert analysis can lead to success for a 100% solar residential project. Distribution network service provider AusNet had significant concerns about potential network impacts of the 15 plus megawatt solar PV capacity that developer Intrapac Property was proposing to install in the Kinley residential and town centre development in the east of Melbourne, the capital city of Victoria state. AusNet's electrical distribution network includes a low voltage (LV) and medium voltage, up to 22 kilovolts (kV) power distribution network in eastern Victoria and Melbourne's eastern and northeastern suburbs.

Far from limiting solar to a third of the development's approximately 3,200 residential homes and townhouses, Intrapac's vision is '100% solar', involving some 50,000 solar panels. For perspective, this is roughly equivalent to having a mid-sized solar PV farm in Melbourne's eastern suburbs and part of Lilydale town centre.

Melbourne-based advisers Clean Technology Partners (CTP), which global technology advisers DNV acquired last September, worked with Intrapac to establish the '100% solar' vision. CTP assisted with analysis of the power elements of the large mixed-used precinct.

With the scale being more than three times the normal allowable penetration for

residential solar, AusNet needed assurance. CTP worked closely with Intrapac and AusNet to prepare studies meeting the network operator's requirements. They shared the report with AusNet to provide technical justification for allowing up to 100% of buildings to be installed with rooftop solar PV.

Studying the network impact

CTP's work scope between 2019 and 2022 involved performing detailed power system modelling of the 100% solar case on both the LV and 22 kV electricity networks at the location. The aim was to develop a network model considering the network connections, system load and generation, component parameters, ratings of the transformers and the export limits and control schemes of the inverters.

The two key elements of the project were analysing the thermal loading and steady-state voltage range. Both studies relied on extensive work in establishing the base elements to be installed at each building type on the development, e.g. townhouse, detached home, etc. and the associated maximum and minimum generation and loads.

The first study aggregated all power flows from the housing lots per kiosk transformer at the site and focused on impacts on the 22 kV distribution system around the site and back to AusNet substations. The second study looked at the most affected kiosks and assessed the impacts of the solar installations on the LV networks.

The studies faced some challenges. Notably, there were no existing guidelines or methodologies for assessing the impact of 100% solar penetration on the network. CTP had to collaborate with AusNet to define the tests and acceptance criteria for the studies.

It took two years of intense collaboration and painstaking work to define and produce a model and results that all stakeholders could agree on.

What the studies found

The intense effort led to CTP reporting two main findings.

Firstly, with some modest revision to the standard electrical distribution design for residential developments, the AusNet network could integrate the proposed penetration of solar power. CTP reached this conclusion because the thermal loading was below the threshold with only minor changes to the standard distribution designs included in the '100% solar' vision, and the pre- and post-connection voltage swings were within the manageable range of +10%/-6% specified by AusNet.

Secondly, the study demonstrated that using the household inverters in-built Volt-VAr response mode would be sufficient to manage voltage swings on the network. These were particularly evident on the LV side of the transformers and the study reviewed different options for addressing these, whilst minimising any lost generation for the households. Volt-VAr (Volt-Amps Reactive) are solar PV inverter settings that manage voltage and counter the undesired impacts that solar power generation can otherwise have on the grid. Through dynamic reactive management of power, Volt-VAr keeps power within specified limits to enable greater solar PV penetration to networks.

Applying the findings

The electrical distribution design in the final report deviates from the AusNet standard in that around 5-10% fewer homes were connected to each 500kVA transformer than would be standard. This resulted in a few more 500kVA transformers across the residential portions of the development than would be normal.

Another mitigation measure was that all inverters were modelled using the Volt-VAr response mode included in the Australian standard for solar inverters at the time, using settings agreed with AusNet.

The combination of modest additional infrastructure and the Volt-VAr response mode in the inverters enabled CTP to demonstrate the site would not exceed thermal limits or voltage limits.

Meeting the ambition for the residential buildings in Kinley to be 100% solar-powered led to the project recently achieving a 6 Star GreenStar rating. This is awarded by the Green Building Council of Australia (GBCA) for 'world-leading' community, environmental and sustainability measures.

Learnings for residential solar projects

In broad terms, the studies at Kinley identify how minor modifications to the 'standard' electrical distribution design approach for residential developments can enable networks to accept high volumes of solar power within distribution code limits.

A side benefit is that the work has validated some benefits of the inverter power quality response modes that have become a feature of Australian Standards in recent times. But the biggest learning is that Kinley reinforces the message that thinking early in the whole development planning process about potential network impacts from integrating community solar PV onto the grid is a key to success.

Regional and global implications

The learnings from this case study could be applied to reduce the time and effort significantly for any such projects in the future. CTP's work on Kinley with Intrapac and AusNet are timely as Australia's electricity system begins to transition away from fossil fuels more rapidly than previously expected.

Lachlan Bateman

As the Australian Energy Market Operator (AEMO) December 2022 roadmap for reaching 100% renewable generation in the national energy markets by 2025 makes plain, this will require power grids that can handle more renewable energy while avoiding power disruptions and reducing costs for consumers.

Solar capacity deployments in Australia could potentially reach 1.9 terawatts by 2050, according to the August 2022 Net Zero Australia report by the universities of Melbourne, Queensland and Princeton. The vast majority of Australia's solar PV installed base has come from rooftop solar. Australian residential solar PV is increasingly popular and has some of the lowest costs in the world, according to a May 2022 update from the International Renewable Energy Agency.

As DNV's Energy Transition Outlook (ETO) also points out, Australia also benefits from having a larger average floor area per household compared with, say, Japan and South Korea, creating a comparative advantage for rooftop solar.

DNV forecasts that globally 20% of all solar generating capacity worldwide will be installed on rooftops and commercial buildings by 2050.

Small installations offer flexibility and local security of supply, and these advantages will ensure that rooftop and micro-grid-sized installations will grow significantly in absolute terms, though their market share will decline. Studies like the Kinley project add to the knowledge base that can support the growth of rooftop solar and its integration into networks.

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