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FlexForum Insights

Making better use of available distribution network capacity will enable more affordable and reliable electrification

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FlexForum insights: making better use of available distribution network capacity will enable more affordable and reliable electrification

Main points

The FlexForum gathered a series of insights and questions while developing Flexibility Plan 1.0[1] about the implications for electrification and uptake of flexibility of network access and connection arrangements.

We think that network access and connection arrangements provide some of the practical levers for making trade-offs between supporting electrification and ensuring an affordable and reliable power supply.

FlexForum discussions so far have focused on how to make the best use of existing distribution networks by adopting more sophisticated techniques for allocating network capacity. Making better use of available capacity involves identifying and allocating spare network capacity across each connection (or a group of connections) across time and location to match the available real-time capacity of the local network or power system.

Shifting to more dynamic approaches for allocating and using spare network capacity requires extensive new capability, processes, and practices, and particularly, significant investment in digitalisation across the supply chain. There are several contractual, pricing, and practical questions to work through to apply dynamic allocation approaches.

The FlexForum wants to start a conversation about how to develop and implement more dynamic approaches to allocating available network capacity. The questions to be resolved range across consumer, contractual, pricing, and practical capability issues, including:

- What is the purpose of identifying and allocating spare network capacity? How does the approach work alongside other network operational practices and market activity?
- What is in it for the consumer? What do we need to do to understand and respond to consumer expectations regarding access to the network?
- What is the contractual construct and nexus between consumers, retailers, flexibility suppliers and distributors?
- How does network pricing (and flexibility payments and other financial signals) work alongside and support dynamic network access?
- What approach should be taken to calculating and applying dynamic approaches? What is the underlying capability required?
- What experiments and practical testing are needed to work out how to make better use of existing network capacity?

More information on the FlexForum and its members can be found at **New Zealand's FlexForum**

To have a conversation or to send your thoughts and views, please contact us at **info@flexforum.nz**

[1] You can find the Flexibility Plan 1.0 here.

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FlexForum insights and questions relating network access and connection arrangements

The FlexForum gathered a series of insights and questions between February and August 2022 about the implications for electrification and uptake of flexibility of network access and connection arrangements.[2]

The insights and questions are collated here to assist a broader discussion and learning-by-doing about the range of options available to the electricity sector now and in the future to make the best possible use of available network capacity. This will help to ensure households, businesses and communities have the greatest possible opportunity to use distributed energy resources (DER) and flexibility and have a more affordable and reliable power supply.

Electrification means households and businesses will increasingly rely on the power system

Electrification means households and businesses will rely more on the electricity system, and particularly distribution networks, and will change the relationship between consumers, the power system and market.[3]

Electrification of transport, heating and cooling and commercial processes – and the resulting growth in DER – will result in significant increase in demand for distribution network capacity, initially, but not exclusively, at the low voltage level. The increased demand for network capacity, if not managed appropriately, could cause over-loading of lower-voltage feeders[4] because demand for capacity on a connection-by-connection basis exceeds the traditional planning assumptions.

The FlexForum thinks that network access and connection arrangements provide some of the practical levers for making the trade-offs between supporting electrification and ensuring an affordable and reliable power supply.

Smarter management of this increased demand for network capacity can ensure that consumer preferences and expectations of the distribution service can be met within the limits of existing network capacity.

A key touchpoint for households and businesses as they electrify and a key factor in their choices about DER and flexibility is their connection to the distribution network.

The electricity sector needs to make sure that each household and business has the network connection and network access they need to turn the lights on, drive about, make widgets, keep warm (and cool), produce power, and support the operation of the power system with the flexibility of their DER.

At the same time, we need to keep things affordable, which means making the best use of available distribution network capacity. Practically, this means that, at times, demand for

> *"Electrification of transport and process heat will create a substantial increase in electricity demand. It will be critical that:*
>
> - *these networks are operated and maintained as efficiently as possible,*
> - *that all alternatives to traditional investment are considered,*
> - *and that further investment in those networks is minimised."*
>
> *Electricity Authority, Energy transition roadmap - Supporting an efficient transition to a low-emissions energy system*

[2] See FlexForum session 11 23 June 2022 at FlexForum: Session Eleven

[3] Predictions of the nature and scale of change in use of the power system and distribution networks are covered in a range of locally and internationally produced reports including from the Productivity Commission (its 2017-08 inquiry into Low-emissions economy), the series of reports from Transpower, and most recently, the BCG The Future Is Electric report.

[4] The increased demand for network capacity is expected to affect a range of network performance measures, including thermal capacity and voltage performance.

network capacity may exceed what is available and there will be choices between coordinating use of the network and building bigger networks.[5]

The Flexibility Plan 1.0 includes several steps relating to network access and connection arrangements

The Flexibility Plan 1.0 includes several steps relating to network access and connection arrangements, with three broad themes to be explored to ensure distributors, retailers and flexibility suppliers have the capability, processes, and practices needed so households, businesses and communities can easily connect and use DER and flexibility.

There are three related themes.

1. **Understand how to make best use of the existing network** by identifying the capability needed to assess and allocate the available physical capacity on a network based on actual network and market conditions, in near real time.[6]	2. **Make sure the connection requirements make it as easy as possible for households, businesses, and communities to electrify and use flexibility**, without adversely impacting security and affordability.[7]	3. **Understand the network design and planning practices that are needed to make sure that networks are built to match the changing uses of and demand for network capacity**, while providing an affordable and reliable service.[8]

The FlexForum has focused on how to make better use of available capacity

The FlexForum has focused on how to make the best use of available network capacity by adopting more sophisticated techniques and practices. Doing this is expected to help to maximise opportunities to consume and produce electricity while minimising service disruption and service costs.

These more sophisticated techniques require distributors, retailers and suppliers, DER manufacturers and DER owners to obtain more sophisticated capability to enable the associated processes and practices. This capability will take time to develop.

Using flexible DER to do more with less depends on the approach to allocating network capacity. The amount of new network needed depends on the methods for allocating network access and ability to use flexibility to manage use of our distribution networks.

[5] The BCG The Future Is Electric report suggests savings of $10 billion in net present value terms by 2050 are possible from developing a much smarter, more flexible electricity system.

[6] Refer Flexibility Plan, Step #11 to explore the use of dynamic operating envelopes for managing access to the network for consumers' DER

[7] Refer Flexibility Plan, Step #9, to ensure connection requirements enable rapid uptake of DER, including accounting for the flexibility of DER, step #25 to identify appropriate minimum technical standards for devices, and step #27 to make sure connection processes enable streamlined uptake of DER

[8] Refer Flexibility Plan Step #10 to ensure network design and planning practices accommodate rapid uptake of DER, including by accounting for the flexibility of DER

A brief overview of network access and connection arrangements

Network access is the physical and operational parameters for each connection

Households and businesses want a connection that lets them consume and produce power based on their circumstances, preferences, and the costs of the associated distribution service.

Each network connection reflects a set of historical choices about the amount of network access (and quality of service) required and paid for by the customer and provided by the distributor.[9]

Distributors typically set out the physical and operational parameters for network access and connection in a Connection Standard (or Policy).[10]

Each connection has a fixed physical capacity which determines how much electricity the household or business can draw from the network for consumption (import) or can generate and send into the network (export) at any point in time.

The connection capacity will reflect the preferences of the household or business, and technical parameters applied by the distributor to achieve safe and secure operation of the network. For example:

When an application for connection is made, WELL will agree with the relevant Party the voltage and capacity at which the Party will be connected in accordance with WELL's normal practice for the type of load to be supplied. WELL may specify a different connection voltage to avoid potential disturbance caused by the Party's Equipment, or for other technical reasons, or may agree alternative methods for minimising the effects of disturbing loads. The Party must take any reasonable steps to keep its Demand within the agreed supply capacity. ….[11]

The technical parameters for distinct types of connection are translated into contractual requirements via the Distributor agreement (between the distributor and retailer) and Customer contract (between the retailer and customer).

Network access for consumption (import)

Most households in Aotearoa New Zealand have a 15-kilovolt ampere (kVA) connection, notionally allowing the 'import' of up to 15kVA from the network at any point in time. The capacity of business connections depends on their specific requirements and can be many megawatts.

The size of the connection does not guarantee a continuous supply at that level. Distributors typically include contractual terms that the distribution service can be disrupted for maintenance, in emergencies, or by agreement. The connection or pole fuse may fail before the connection capacity is reached as protection in the case of grounding or a short circuit. Or network assets, such as transformers, may fail, for example if multiple households were to seek the full 15kVA simultaneously. (Good design practice leads distributors to build in a prudent degree of diversity in their demand assumptions, avoiding over-investment.)

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[9] As a sidenote, the location of the point of connection between a customer and the distribution network may not be straightforward. For an overview of the issues see: Ownership and maintenance of customer service lines.

[10] For example, this is the Wellington Electricity Distribution Code and Network Connection Standard, available at: https://www.welectricity.co.nz/getting-connected/network-connection-standard/. Connection requirements are set out in sections 7.3.2 and 7.4

[11] Wellington Electricity Distribution Code and Network Connection Standard, 7.3.2

The import threshold for households and many smaller businesses has typically been created on a set-and-forget basis, without the need to understand more deeply for what devices and equipment the homeowner or business operates, the capacity used at the connection or local network conditions.

Network access for generation (export)

Each connection able to produce power has an 'export' threshold specified in a distributor's connection arrangement, with different requirements for distributed generation (DG) that is less than or greater than 10kW.[12] Distributors are required to publish areas where there is no room for more DG.[13]

The purpose of the technical requirements and export thresholds for DG is to ensure electrical safety and to avoid failure of network assets and damage to the equipment and devices of other customers connected to the network.

A key technical requirement in AS/NZS 4777.1 – 2016 is that single phase (the typical 15kVA NZ connection) DG invertor connections are limited to 5kVA and multi-phase connections shall have no more than 5kVA of phase imbalance. The requirements apply to all equipment able to send power into the network, eg, battery systems.

Distributors are obliged to maintain power quality including voltage performance. The Electricity (Safety) Regulations 2010 require a supply of electricity to low voltage installations to be within +6% of a nominal voltage level of 231V. This voltage range was set assuming little to no DER, particularly solar.

More DER and solar DG, more variable, and behaving less predictably than traditional loads, will require more effort to manage voltage performance. This is necessary to avoid damage to the network, consumer equipment or harm to other customers (eg, dimming and flickering lights, or voltage spikes that can damage computer equipment).[14]

Most distributors in Australia have applied a 5kW limit on connection of small-scale DG (ie, solar), and connection can be refused in areas with considerable amounts of solar DG. This practice was adopted to manage network congestion resulting from a growing imbalance between network demand, generation onto the network and the capacity to export this generation, as more power was exported to the power system from household solar systems. The practice, which reflects a static approach to capacity management, was adopted to avoid risk that was not well monitored or understood. The static approach is being replaced with the introduction of dynamic operating envelopes (DOEs), which are a more sophisticated tool for adjusting and dynamically allocating access to available network capacity, based on the actual conditions on the network.

Networks have been designed to supply expected demand for capacity

Distribution networks are designed and built to meet the expected maximum peak demand for electricity of the households and businesses connected to the network, which is different from an aggregation of all allowable import limits.

Distributors have traditionally relied on observed data demonstrating expected levels of demand diversity between consumers to provide appropriate levels of network capacity available at each connection point. The average individual demand is usually significantly less than the contracted physical connection size to the network, thereby enabling a significant reduction in network

[12] Connection requirements for distributed generation are determined under the Electricity Industry Participation Code, Part 6.

[13] In these areas the distributor can refuse to connect the proposed DG or can require installation of smaller DG or seek a contribution toward an upgrade. Practically it is difficult to define congestion and therefore publish areas of congestion. Distributors have tended to publish a policy on how congestion will be managed through the connection process. Work is underway by some distributors to establish DG hosting capacity at an LV network/neighbourhood level.

[14] Step #18 in the Flexibility Plan calls for a review to voltage limits to ensure they do not create a barrier to uptake of DER. Voltage limits are being updated in Australia to allow a voltage range of 10% above and 6% below the 200-250V range.

design capacity compared with the sum of the physical capacity of each connection. Hence network investment and cost to consumers across the network is significantly reduced. The demand assumed through this right-sizing of planning assumptions is the so-called design after-diversity-maximum-demand (ADMD).

In turn these assumptions will also impact how much transmission capacity is invested in to serve a region.

The ADMD is an estimate of the capacity required to reliably deliver electricity to each connection based on the design 'worst case' scenario conditions.[15] Particularly for a household, the ADMD will be significantly less than the physical capacity of the connection. ADMD assumptions for household connections used in Aotearoa New Zealand range from 1.5kVA to 5kVA.[16]

Diversity of demand, and predictable one-way flow patterns on networks, have meant it has not been necessary to monitor or manage capacity for consumption or generation on a connection-by-connection basis. Maintaining power supply and quality has been straightforward for distributors to achieve under a 'set and forget' basis due to stability and predictability in network use patterns and flows on their networks over time.

Making better use of available network capacity

In an environment where there is increasing demand for network capacity, making optimal use of available network infrastructure would traditionally involve identifying and applying physical or contractual limits on the import and/or export of electricity to reflect the physical limits of the network over time.

Experience has indicated it can be economically preferable (and more affordable for consumers) to have reasonable limits in place during peak times rather than to incur the cost to reinforce networks to provide more peak capacity. For the same reason, the transmission network is not sized to enable all possible flow scenarios – constraints occur frequently, and usually when output from renewable generation is particularly high.

Households and businesses[17] rely on distributors to provide network infrastructure that allows them to consume and produce electricity. The amount of network capacity available on existing networks is generally set by historic decisions and changes to design standards over time, including undergrounding policies. Design standards reflect historical consumer trade-offs between what people were prepared to pay (individually and collectively) for capacity and the safety, quality, and reliability of supply.

However, present-day network use, including DG and DER, means that traditional network design parameters may no longer be appropriate. Capacity is also impacted by the extent to which historic capacity has been partially eroded by infill housing, clean air policies leading to increased heat pump use and other changes in consumption behaviour.

Steps #9 (on connection requirements), #10 (on ADMD assumptions and network design) and #11 (on DOEs) of the Flexibility Plan 1.0 are about ensuring network access and connection arrangements recognise the trade-offs involved in maximising the benefits of network access to consumers individually and collectively as electrification changes how networks are used.

[15] This can typically be to provide for a one-in-twenty or one-in-ten year peak demand scenario.

[16] ADMD assumptions vary significantly depending on where in the network the capacity requirement is being calculated (eg, at a substation or at a GXP) and taking account of residual differences in demand assumptions.

[17] Directly, or indirectly via a retailer.

More sophisticated approaches to allocating available capacity are required

More sophisticated approaches to allocating available capacity will be required to maximise consumer benefits from DER and flexibility.

Current practice for allocating capacity for most connections is to provide a fixed amount of network access for consumption and generation, e.g., most households have a 15kVA (import) consumption threshold and a <5kW generation threshold. Specific analysis is required to facilitate greater than 5kW of generation.

- Import thresholds reflect network design and connection policies and are rarely revisited
- Export thresholds reflect network design and connection policies, subject to Code requirements (Part 6) for small-scale (<10kW) and for larger DG connections.

In general, the above allocations lead to an over-allocation of demand capacity and a possible under allocation of DG capacity depending on what level DG uptake eventuates, i.e., all households or some percentage of households with DG.

Continuing to use a conservative static, set-and-forget approach to allocating network capacity will likely lead to restrictions on connection of DER (eg, electric vehicle (EV) chargers and solar systems), and/or reductions in opportunities to maximise the value of flexible DER, and could drive the need to invest in a larger network, sooner. Capacity restraints could also inhibit the conversion of non-electric processes to electricity.

Studies in Australia[18] indicate the assumptions inherent in setting a static export threshold result in lots of spare capacity being available most of the time. This could otherwise have been used by households and businesses to produce and export electricity and to electrify more of their day-to-day activities, without requiring upgrades to the network.

Better use of available network capacity informs choices about using flexibility and expanding the network

The capability and practices required to make better use of available network capacity inform choices about using flexibility and expanding the network.

Flexible DER can, with the explicit consent of consumers, be used to support the operation of the network by providing extra ability to defer or avoid the provision of upgrades to network capacity. Equally, use of flexible DER on local networks can mean that fewer transmission lines or power stations need to be built and operated across Aotearoa New Zealand.

More routine use of flexible DER, especially as part of the national system, will change the patterns of network use, including potentially creating real or perceived localised network congestion and performance challenges. (Perceived congestion is a result of adopting conservative set-and-forget design parameters without having visibility of actual network capacity and loading in real time.) The capability to make better use of available network capacity will support using flexibility for network, system, and market purposes.

Making better use of available network capacity also affects choices to expand the network. Distributors will need to forecast new demand and DG, and target areas most in need of network upgrades to meet demand and DER growth. The question is how much of the increased demand can be met by smarter use of the existing network, and how much needs to be served via building *more* network.

The Flexibility Plan 1.0 recognises this in step #10 to review ADMD assumptions which underpin network design decisions to account for the expected increase in demand for network capacity from electrification and availability of flexible DER. For example, when,

[18] Initial analysis in South Australia shows that for a typical residential customer, the Flexible Export limit will be at 10kW for majority of the year, only limited below this value for 2% of daylight hours (approximately 50 hours). Refer https://www.sapowernetworks.com.au/industry/flexible-exports/faqs/

where and how EVs are charged will have a significant impact on how large the future ADMD will be and how much network capacity needs to be built. ADMD assumptions and network design practices will flow through to network access and connection arrangements and be a factor in the choices consumers can make about DER.

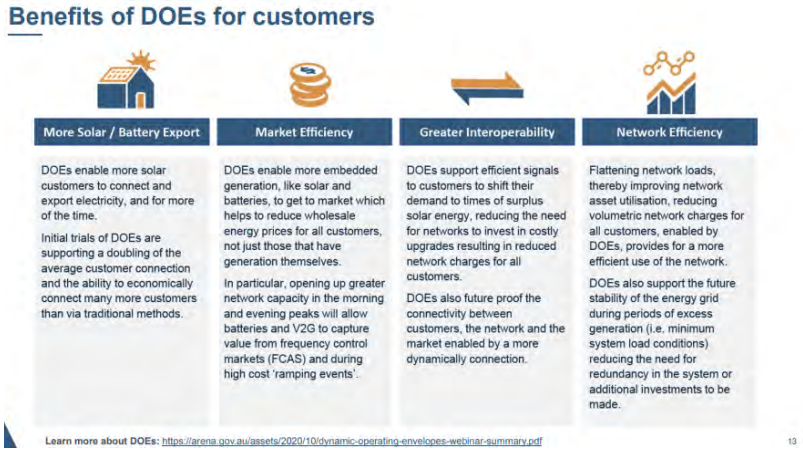
Approaches for identifying and allocating network capacity

The demand for network capacity on the transmission network, and on local distribution networks, changes every hour of every day due to the combination of what households and businesses are doing and whether the sun is shining or wind blowing, how cold or hot the temperature is, and what planned or unplanned outages of network capacity have occurred.

Making better use of available capacity involves adopting approaches for identifying and allocating network capacity at each connection (or a grouping of connections) across time and location to match the available real time capacity of the local network or wider power system.

Dynamic approaches to identifying and allocating capacity across large numbers of connections are being developed in Australia and the United Kingdom. Dynamic approaches are already being used for some larger connections in Aotearoa New Zealand, on a bespoke basis.

DOEs are about providing households and businesses with more network access based on what is available. "The simple philosophy of DOEs is that customers should be free to optimise their energy generation and usage, and provide services to other parties, within the physical limits of the power system. These limits can include local network thermal or voltage constraints identified by the [distributor]... or, potentially, bulk system constraints…"[19]



Source: DEIP Dynamic Operating Envelopes Workstream, Final Outcomes Webinar, 30 March 2022, page 13, at https://arena.gov.au/assets/2022/03/deip-outcomes-webinar-march-2022.pdf. Note, these benefits reflect use of DOEs to set varying export limits, not import limits.

[19] Distributed Energy Integration Program (DIEP), Dynamic Operation Envelopes Working Group, Outcomes Report, March 2022, page 53 at https://arena.gov.au/assets/2022/03/dynamic-operating-envelope-working-group-outcomes-report.pdf

This would support greater access and use of available network capacity to enable households and businesses more opportunities. In turn, this would enable them to better reflect their preferences, or to participate in national or local markets, by offering services to a range of buyers, all the while staying within the boundaries needed to keep the local network safe and stable for all consumers.

Importantly, dynamic approaches are not meant to be used for set-point control – in other words, DOEs should not be used to specify exact levels of output or import from/by a DER: "If more fine-grained, DER or connection set-point control is required (ie, for network services, augmentation deferment, etc…) then appropriate economic or market-based incentives should be used."[20]

Dynamic approaches to allocating network capacity

Dynamic rather than fixed limits are expected to enable better use of available network capacity, and higher levels of electricity exports from customers' solar and battery systems by allowing higher export limits when there is more hosting capacity on the local network.[21]

> *DOEs vary import and export limits for a connection over time and location based on the available capacity of the local network or power system.*
>
> *Source: Distributed Energy Integration Programme*

This overview of dynamic allocation approaches draws heavily on the Australian Distributed Energy Integration Program (DIEP) DOE working group.[22] Dynamic allocation approaches – called dynamic operating envelopes (DOEs)[23] – are being developed as a tool to be used alongside contracted flexibility for managing increased demand for network access by DER.[24]

The operating envelope – the import and export limits applying to a connection – adjust the amount of network capacity allocated to a connection by time and location (ie, dynamically) based on actual network and system conditions. "…[An] operating envelope is a principled allocation of the available network capacity to individual or aggregate DER or connection points. We believe that an operating envelope must thus represent an allocation of all available network capacity up to the physical and operational limits of the network."[25]

An 'envelope' can be adjusted annually, seasonally, daily, or hourly, with the extent of variation depending on technology, experience, and need.

Adopting such a fully dynamic envelope would likely represent a major step, involving considerable investment, for most distributors. As a potential interim starting point for Aotearoa New Zealand, a less dynamic approach, using static seasonal envelopes based on different customer profiles, could be adopted. These envelopes would be derived from historic data. In future, as more real-time network monitoring becomes available, we could then evolve to a more dynamic approach.

The operating envelope, whether static or dynamic, should be the best possible representation of the physical system limits. It is a distribution-level equivalent of the firm limits on flows possible on transmission lines.

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[20] evolve Project, On the calculation and use of dynamic operating envelopes, September 2020, p20

[21] ARENA webpage at https://arena.gov.au/knowledge-innovation/distributed-energy-integration-program/dynamic-operating-envelopes-workstream/, What are Dynamic Operating Envelopes, viewed 30-12-21.

[22] The work of the DIEP DOE workstream is available here, https://arena.gov.au/knowledge-innovation/distributed-energy-integration-program/dynamic-operating-envelopes-workstream/

[23] DEIP, Dynamic Operation Envelopes Working Group, Outcomes Report, March 2022, page 5

[24] For example, refer notes from session 7 …" Current thinking [by the South Island Distributor Group] is to begin with tenders for predictive congestion management services and putting in place dynamic connection contracts / dynamic operating envelopes"

[25] evolve Project, On the calculation and use of dynamic operating envelopes, September 2020, p20, at https://arena.gov.au/assets/2020/09/on-the-calculation-and-use-of-dynamic-operating-envelopes.pdf

Dynamic approaches will be critical to enabling flexible DER to participate in national and local markets

Flexible DER will have a growing impact on network operation as it increasingly participates in national markets for energy and ancillary services and is dispatched by Transpower, the System Operator (especially after the introduction of Dispatch Notification product in April 2023).

Distributors can manage sudden falls in load. Restoring load (including after a period of load control) requires more careful management. A fall in wholesale prices, due to increases in wind or solar generation across a part of Aotearoa New Zealand, could see many distributed batteries, EV chargers and smart hot-water cylinders being dispatched on by the System Operator. Similarly, large numbers of DER, such as household batteries, are already being armed to respond at short notice to a fall in system frequency on the grid.

About every five minutes of every day, the System Operator uses security-constrained economic dispatch, via the SPD tool, to work out which power stations to run, which flexible load to dispatch on or off, and which response resources to arm for reserves. However, by design, this tool can only see as far as the grid exit point (the boundary between the transmission network and distribution network) and has no visibility of the security and power-quality constraints on the distribution networks. As with the transmission grid, the capacity available on distribution networks can change materially at short notice – for example due to storms, car versus pole outages, every-day network switching and planned outages.

To enable flexible DER to provide services to national markets in a way that keeps distribution networks safe and stable, and maintain power quality to consumers within legislated limits, distributors will need to provide operators of flexible DER with network access that represents not just maximum physical operating limits, but possibly also physical limits on the rate-of-increase of demand or output that the network can handle to avoid creating unmanageable surges (which could happen if the wholesale price, or the system frequency, suddenly drops or increases).

With more DER operating, distribution networks will increasingly need to be operated similarly to the transmission network.

Experience in South Australia

A dynamic approach to allocating network access was implemented in South Australia in December 2021, with trials or planning underway in other Australian states.

SA Power Networks (SAPN) – the distributor in South Australia – is using DOEs to set dynamic export limits for new or upgrading DG (ie, solar) in designated areas with export-related network congestion.

SAPN wants to use DOEs because its "…distribution network was built many years before solar, and reverse power flows from solar are now starting to exceed the 'hosting capacity' of parts of the network, especially on mild Spring days. This lowers the performance of customers' solar systems, and causes voltage issues, including for non-solar customers, in some areas with a lot of rooftop solar. It is also starting to exceed the reverse power ratings of some of our major plant at some substations."[26]

A household installing or upgrading their solar system in designated areas now has two options:[27, 28]

- a fixed export limit of 1.5kW per phase (versus the previous 5kW per phase) all year round

[26] SAPN FAQs at https://www.sapowernetworks.com.au/industry/flexible-exports/faqs/

[27] For more detail, see https://www.sapowernetworks.com.au/industry/flexible-exports/.

[28] The model standing offer is available here, https://www.sapowernetworks.com.au/public/download.jsp?id=9704. See clause 4.2, particularly (d), (e) and (k).

- a flexible export limit varying between 1.5kW and 10kW per phase, subject to available network capacity at that location throughout the day and the reliability of the internet connection. SAPN analysis indicates the export limit will be 10kW per phase for 98% of the time.

The flexible export limits – the DOE – are applied through a model standing offer setting out the terms and conditions for basic connection services for retail customers who are small generators.[29]

Thinking on the operational steps for implementing a dynamic approach

The operational steps needed to implement a dynamic approach in an operational setting are a work in progress; there is not yet a definitive approach operating at scale. An approach identified by the evolve Project[30] highlights a range of new capabilities, processes, and practices to be obtained by distributors, flexibility suppliers and other parties managing DER.

Determine the initial power flow – the first step is to determine the available hosting capacity of the network before technical or operational limits by identifying the initial or uncontrollable power flow due to uncontrollable demand and generation. "…as dynamic operating envelopes represent a form of active network management, they can only be utilised for DER assets or connection points that are able to respond to external signals. In this context, to identify the available hosting capacity it is necessary to first determine the initial operating state of the network due to uncontrollable demand and generation flows." In other words, the distribution network would still need to be sized to meet all non-discretionary or non-shiftable load. Spare network capacity would be allocated to discretionary load or generation.
Identify the DER or connection points that will use the available network capacity – the next step is to identify the DER assets or connection points that need to use the available hosting capacity. "To allow the remaining network capacity to be allocated it is important to know the network location of the DER assets or connection points to which the remaining capacity will be allocated. This requirement arises due to the non-trivial relationship between DER or connection point location in the network, the injected real and reactive power at each node, and the resultant node voltages and branch flows in the electricity distribution network." The location or granularity of the DOE needs to be defined. The choices are at the low voltage feeder level, the distribution transformer level, or the connection point level. DOEs are being implemented in Australia at the connection point level. Applying DOEs at a feeder would require mechanisms to determine connection-level allocations between competing retailers (or sub-ICP traders).
Calculate and allocate the available network capacity – the next step is to allocate the space capacity using a principled approach. "Once the initial operating state of the network is measured or forecast it is possible to calculate how to allocate this remaining network capacity. Almost always there will be infinitely many ways of allocating this remaining capacity…" The DIEP DOE working group developed export hosting

[29] The model standing offer was approved by the Australian Energy Regulator as part of the SAPN revenue determination for 2020-25, refer Final decision - SA Power Networks distribution determination 2020-25 - Attachment 17 - Connection policy - June 2020 (section 17.1) and Connection Policy for 2020-25 (section 16)

[30] evolve Project, On the calculation and use of dynamic operating envelopes, September 2020, p21-23. All the quoted material in the figure is from this report.

capacity allocation principles, noting more work is required to define how these principles are applied in practice:[31] • EDBs are responsible for setting DOE limits, with the calculation methodology used to determine the limits being transparent and subject to stakeholder consultation. • Allocation should seek to maximise the use of network export hosting capacity while balancing customer expectations regarding transparency, cost and fairness. • Capacity allocation can initially be based on net exports and measured at the customer's point of connection to the network • Capacity should be allocated to small customers irrespective of the size or type of customer technology (eg, solar or batteries) at the customer premises. In the near term, DOEs should be offered on an opt-in basis with capacity reserved only to make good on legacy static limit connection agreements, with efficient incentives provided for customers to transition to DOEs over time.
Publish the operating envelopes – the distributor needs to publicise the available capacity in the form of an operating envelope over the chosen period, eg, daily or seasonally. Project Symphony[32] is calculating and publishing DOEs in a day ahead manner using 5-minute interval data (not live) for each connection point.
Allow aggregation if possible – enabling retailers and flexibility suppliers to manage the network access available to their customers should result in greater opportunities to maximise the value of DER and flexibility in the portfolio. The "…aggregation is not a straight summation but requires additional calculations to be undertaken. Notwithstanding this additional calculation requirement, the ability to allow retailers or aggregators to aggregate within their own customer base provides important flexibility to achieve specific individual and aggregate optimisation outcomes. These calculations can however be performed by individual retailers or aggregators after the operating envelopes are published." The level of the network across which DOEs can be aggregated will very much depend on at which part of the network the binding constraints are – for example if capacity headroom is lowest at low-voltage level, aggregation would not be possible across multiple feeders.

[31] DIEP, Dynamic Operation Envelopes Working Group, Outcomes Report, March 2022, pages 52-53

[32] See here https://arena.gov.au/projects/western-australia-distributed-energy-resources-orchestration-pilot/ and https://arena.gov.au/assets/2021/09/project-symphony-vision-and-impact-pathway.pdf

Practical steps toward providing varying levels of network access to reflect network conditions

Shifting to a dynamic approach to allocating and using network capacity requires new capability, processes, and practices, as well as potentially substantial enabling investment in network monitoring and communication capabilities.

Experience gained so far in Australia will help answer some, but not all, of these questions. Dynamic approaches were developed in Australia to manage network and system reliability issues arising from export of significant volumes of power from rooftop solar. Given this initial focus for design and application, the DOE working group concluded dynamic approaches should not be used to apply import thresholds without further consideration. **There are multiple trials underway testing the use of dynamic approaches to manage limited capacity for imports to accelerate this learning**.

In contrast, the immediate reason for applying dynamic access thresholds in Aotearoa New Zealand is likely to be to maximise use of available network capacity while managing consumption-related network and system reliability challenges in a world where new investment is being minimised to maintain affordability. In time, increases in rooftop solar, and vehicle-to-grid capability, could see New Zealand's export challenge more closely resemble Australia's (at the same time as needing to manage imports).

The Flexibility Plan 1.0 includes several steps relating to network access and connection arrangements, including exploring dynamic operating envelopes and checking connection arrangements are ready to enable households, businesses, and communities to maximise the value of DER and flexibility.

There are several contractual, pricing, and practical questions to work through to apply dynamic allocation approaches.[33]

Consumer and contractual questions

A key insight from the work undertaken in Australia is not to introduce dynamic approaches without extensive consumer engagement to build trust and earn consumer permission to do so.

Changes to connection arrangements and customer contracts are required to offer varying levels of access to the network. Consumers will need the ability to agree to a varying level of access or choose a viable alternative that reflects network circumstances. Things to consider include:

- consumer expectations about their level of access to network capacity, particularly to support electrification, will increase demand for network capacity at peak time both individually and collectively, and simply building larger infrastructure to meet that increasing demand will impact affordability. Implementation will need to manage customer expectations around changes to existing levels of access (most households have a 15kVA connection and, if they ever think about it, probably expect they can use this fully at all times)
- exactly what is to be achieved, eg, maximise solar exports, minimise unserved EV charging, equally allocate capacity for distinct types of networks and DER penetration
- choices will need to be real and offer the customer 'something'. SAPN is offering households in designated areas a fixed export limit of 1.5kW/phase or a flexible export limit that varies between 1.5kW to 10kW/phase. This offer was approved by the Australian Energy Regulator

[33] The list of questions draws FlexForum discussions and on the Distributed Energy Integration Program, DER Market Integration Trials, Summary report, September 2022, page 17 go to https://arena.gov.au/assets/2022/09/der-market-integration-trials-summary-report.pdf

- how to agree dynamic approaches with consumers, and the contractual construct and nexus between consumers, retailers and flexibility suppliers and distributors.

Pricing questions

Network pricing (alongside flexibility payments) provides a neutral, objective tool for communicating the amount of capacity available at a point in time and place and allowing trade-offs to be made.

Network price signals indicating the cost of using available network capacity would leave consumers, retailers, and flexibility suppliers to make choices about how they manage their use of network capacity. Consumers, retailers, and flexibility suppliers are far better placed to make choices which optimise use of network capacity, so long as they have useful information.

The distribution pricing principles (a)(iii) expect pricing to 'reflect differences in network service provided'. Dynamic connection agreements will need accompanying price structures which reflect the varying levels of access relative to standard connection agreements.

Project Edith[34] – a trial running in Victoria, Australia, is exploring the interaction between network access and network pricing:

- "Dynamic operating limits (DOEs) that can allow customers to use more energy or export larger amounts of their rooftop solar at times when there is extra capacity on the network.
- Dynamic network prices (DNPs) for customers who already have a retailer or aggregator managing their battery in a VPP. This would be a price structure that changes day to day based on the daily flows on the network. For instance, on a sunny mild day the import cost may be cheaper in the mid-afternoon to incentivise charging a battery or electric from the excess solar on the network, but on a warm cloudy day the cheaper period moves to the early morning to encourage overnight charging."

Practical capability questions

Providing consumers with varying levels of access to network capacity will require the distributor, the consumer and the retailer or flexibility supplier to have extra capability. Things to consider include:

- developing a nationally consistent approach to calculating and applying dynamic approaches, including obtaining the underlying capability such as requiring network visibility, data capture, communication, and processing capability
- identifying how to calculate thresholds using a reasonable and efficient approach which provides clarity about how often varying access limits are binding and by how much. The arrangements will need to explicitly recognise the potential value or consumer utility lost through 'reducing' access
- exploring the capability required for network operators to manage the network and orchestrate DERs in emergency situations, at specific locations, when the distribution or transmission network are congested, there is no available capacity and immediate action is required to maintain quality and reliability of supply
- exploring the capability required to ensure coordination between network operators and the system operator to enable full integration of DER and flexibility into the electricity system and markets
- exploring what data capture, communication and processing capabilities need to be identified and obtained to apply and use more dynamic approaches, including for the distributor, the consumer and the retailer or flexibility supplier to send and receive instructions to vary access and report 'compliance' with the operating envelope. A key part of identifying new data-related capabilities will be to ensure fit-for-purpose arrangements for maintaining data security and managing data rights (including determining what is meant by fit-for-purpose)

[34] More information on Project Edith is available here: https://www.ausgrid.com.au/About-Us/Future-Grid/Project-Edith.

- exploring capabilities and protocols for monitoring and managing performance within varying access limits to ensure no unreasonable or unfair outcomes for individual customers or consumers generally.

Further reading

More information on how network access and connection arrangements might be configured to support electrification and to maximise the value of DER and flexibility is available in these websites and papers.

- SA Power Networks webpage describes its Flexible Exports connection option. The option has been available from 14 February 2022 to new or upgrading solar customers in in the most congested parts of its network. Go to: https://www.sapowernetworks.com.au/industry/flexible-exports/ and https://www.sapowernetworks.com.au/future-energy/solar/
- The Distributed Energy Integration Program is a collaborative forum where organisations come together to share knowledge and work together towards a common goal. DEIP is driven by the premise that collaborating on shared issues and mutual goals will more efficiently identify knowledge gaps and priorities, as well as accelerate DER integrated in the interest of all consumers. Go to: https://arena.gov.au/knowledge-innovation/distributed-energy-integration-program/
- The DEIP Dynamic Operating Envelopes Workstream concluded in December 2021. Go to: https://arena.gov.au/knowledge-innovation/distributed-energy-integration-program/dynamic-operating-envelopes-workstream/ for the workstream outcomes, including the Outcomes Report identifying the future policy, regulatory, technical and industry actions needed to implement a nationally consistent model for DOEs that will work in consumers' interests.
- The DEIP published a report in September 2022 to present a summary of the approaches to DER market integration being tested by AEMO's Project EDGE, Western Power's Project Symphony, Ausgrid's Project Edith and Evoenergy's Project Converge. Go to https://arena.gov.au/knowledge-bank/deip-der-market-integration-trials-summary-report/
- Project Edith is an initiative that aims to display how the grid can facilitate technology and green energy solutions (like Virtual Power Plants (VPPs)) to participate in energy markets while staying within distribution network capacity limits. Go to https://www.ausgrid.com.au/About-Us/Future-Grid/Project-Edith

More information on the FlexForum and its members can be found at **New Zealand's FlexForum**

To have a conversation or to send your thoughts and views, please contact us at **info@flexforum.nz**