To: Mr Peter Price, Dr. David Pointing and The API Board

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Date: 02nd May 2022

MANAGING MINIMUM DEMAND IN THE ELECTRICITY NETWORK

VISION

"To engage with our consumers and regulators to drive a safe, reliable and sustainable energy transition."

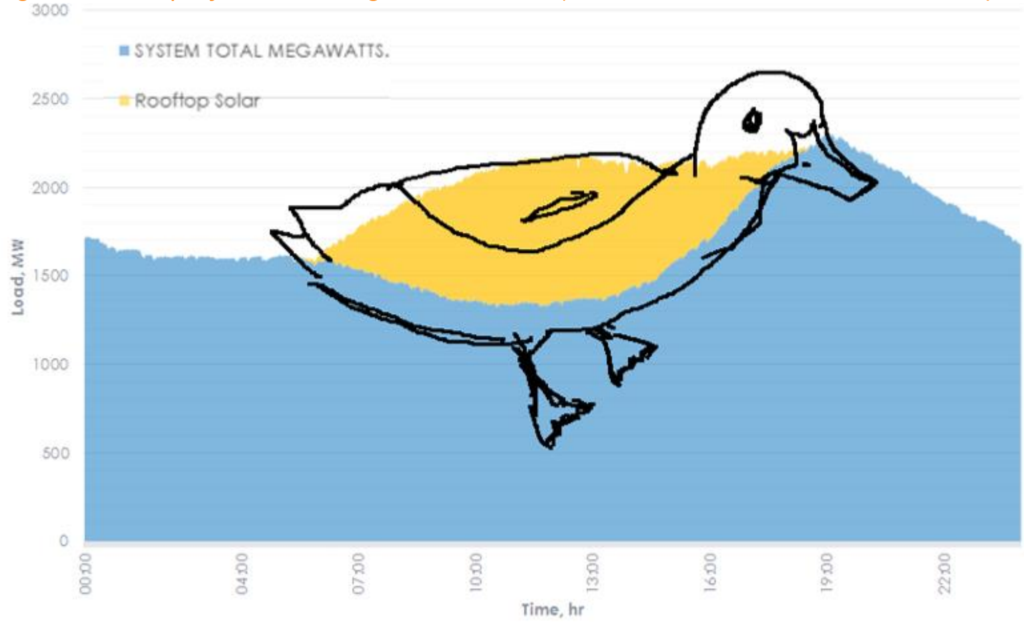
Executive Summary

This paper was developed during Australian Power Institute's Summer School program 2022. The recommendations are based on the existing and emerging industry practices and leverage the information shared by leaders and innovators from Network Service Providers (NSPs), Market Operator and Regulators. This paper provides recommendations for managing the cultural, technical, social and political impact of the minimum demand and penetration of rooftop PV.

Minimum demand is causing unprecedented disruption across the energy sector and will permanently change the industry. Whilst this is a challenge, it is also an opportunity to benefit from this revolution. The impacts on non-synchronous generation on the network can be severe and lead to grid-wide blackouts with massive financial and reputational implications, comparable to the impact of the catastrophic failure in South Australia in 2016, which resulted in a loss of $360 million for business.

Rooftop PV penetration has a major impact on the shift in consumer profile. A new period of minimum demand in the middle of the day has now emerged. The minimum load is approaching a point where it will be below the least amount of load required to maintain the network stability. This phenomenon is commonly referred to as the 'duck curve' is illustrated in Figure 1.

Figure 1: Load profile illustrating a 'duck curve' (Western Australia 28 October 2018)



Market players, Regulators and NSPs, are exploring innovative ways to overcome the challenges of minimum demand. The solution requires a holistic approach and knowledge sharing involving all key industry stakeholders. NSPs are currently trialling a number of initiatives like regulatory changes, enhancing control capabilities, use of synchronous condensers to provide inertia and system strength.

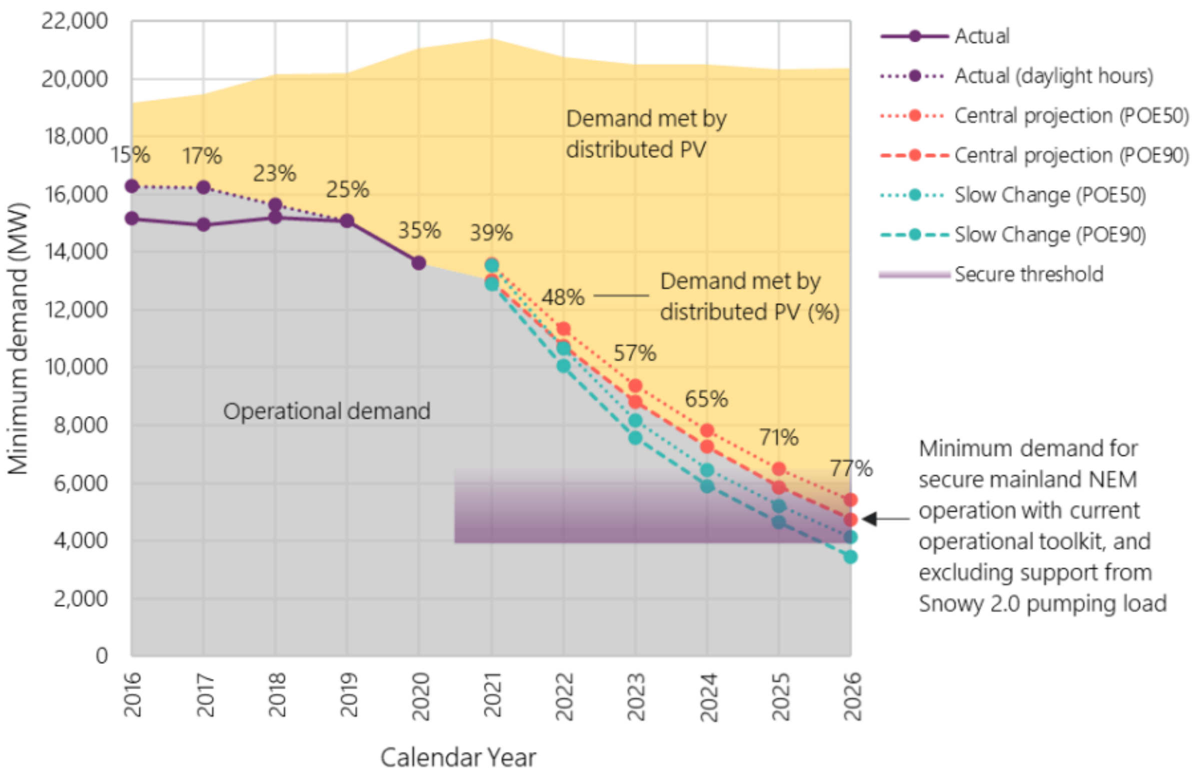
Each strategic recommendation in this paper is structured as a strategic initiative for NSPs, to provide a range of actions to help NSPs deal with the minimum demand challenge in a sustainable manner.

1. **Understanding the consumers** improves consumer related information available to NSPs and improves modelling capabilities, enabling more targeted strategies with higher benefits to stakeholders.
2. **Understanding NSPs' role** improves the alignment of key market players, delivering efficiencies for NSPs and a more equitable distribution of the benefits and costs of the transformation.
3. **Managing the assets** is aimed at developing adequate asset management strategies to incorporate new assets while maintaining performance of the existing network.
4. **Operating the network** delivers efficiencies in network operations by targeting demand and increasing automation.
5. **Transforming the network** provides a list of potential trials for NSPs to remove uncertainty around suitable solutions for different parts of the network.
6. **Delivering the transformation** proposes actions to streamline delivery and reduce costs.

1. Background

The growth of rooftop solar PV has caused a dramatic shift in the system demand profile to a point where it has an impact on network performance. The Australian Energy Market Operator (AEMO) has identified that in National Electricity Market (NEM), the system minimum demand is forecasted to decline rapidly to below the power system security level in 2026, as shown in Figure 2.

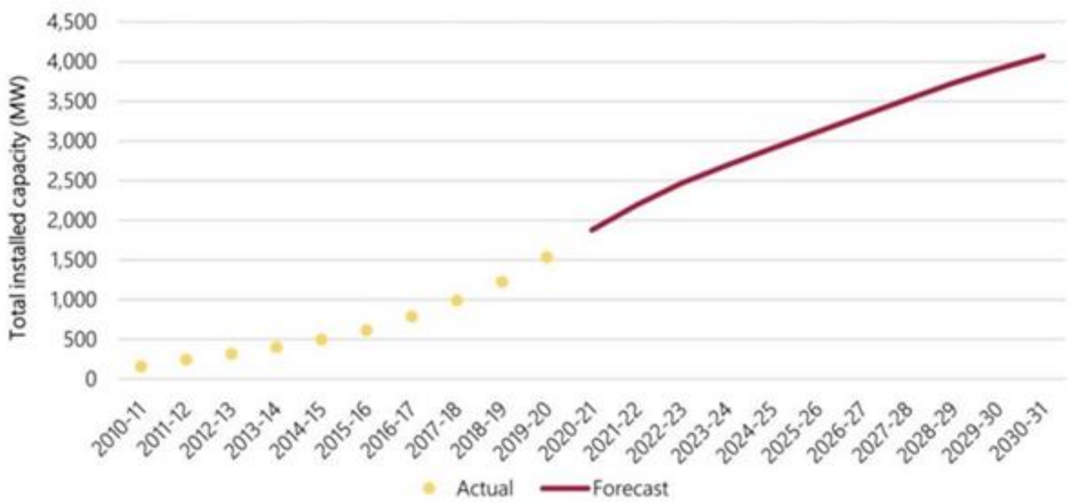
Figure 2: Minimum demand on the NEM Mainland by AEMO



Source: AEMO NEM 2021 Electricity Statement Of Opportunities (ESOO)

These issues are expected to increase in complexity with continuing uptake of residential PV and the increase in capacity of individual installations. The severity is such that the existing system and network management mechanisms will no longer be sufficient in the near future. Figure 3 shows the forecast of behind-the-meter PV over this decade. As shown, capacity is expected to double in the next nine years from approximately 2,000 MW to 4,000 MW.

Figure 3: Actual and forecast total installed behind-the-meter PV, 2010-11 to 2030-31



Source: AEMO NEM 2021 Electricity Statement Of Opportunities (ESOO)

The real-time challenges include but are not limited to insufficient system inertia, network over voltages, excessive reactive power absorption by generating units, insufficient load for Under Frequency Load Shedding (UFLS) and protection mal operations. The long-term impact includes increased risks of asset failure due to overheating from dual power flow.

If any of the challenges is not managed properly, the community could experience frequent power disruptions, or in the extreme case, blackouts. The South Australia blackout in September 2016 has caused an outage that lasted for hours, cost business a total of $360 million, and had international repercussions.

A significant portion of residential rooftop PV cannot be remotely controlled, which increases the risks to the networks as they will keep exporting even when there's excess load in the network.

In terms of regulatory and policy, the tariff structuring is currently not fit for purpose, whereby, there is either a two-part (daily charge and cents per kWh usage charge) or a slightly declining block rate tariff with a daily charge and typically two block rates.

In addition, there is a misalignment of consumer sentiment whereby households are drawn to taking up rooftop PV with the hope of reduced bill costs and interest/willingness to contribute to the energy transition directly. There is limited understanding of the services that DNSP provide to consumers in general (system stability and availability).

The price of inaction will be to have a system that is not prepared for the futureThe impacts on non-synchronous generation on the network can be severe and lead to grid-wide blackouts with massive financial and reputational implications, comparable to the impact of the catastrophic failure in South Australia in 2016, which resulted in a loss of $360 million for business.

2. Discussion

To combat the ever-increasing levels of non-dispatchable generation being installed across networks in Australia, utilities and other participants have trialled several possible solutions such as Dynamic Export Limits, Storage, Synchronous Condensers and Tariff Reform to name a few, with varying degrees of success. It is evident that no one solution will solve the whole problem, and an approach using a mix of these solutions will be necessary.

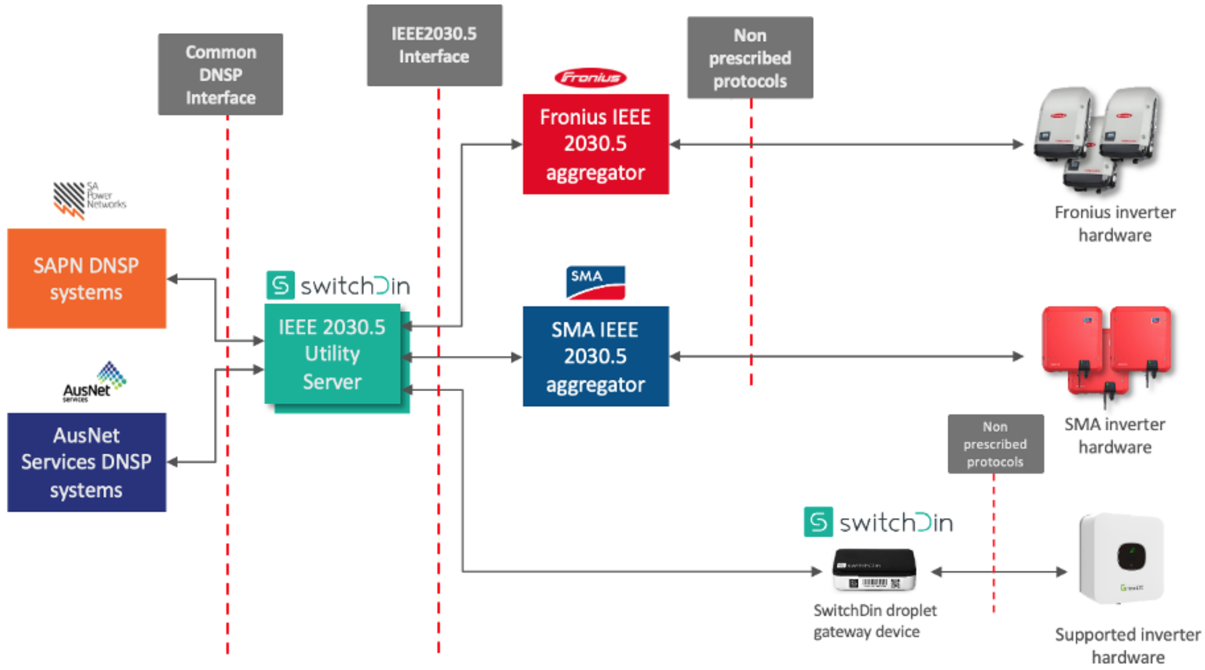
South Australia, who has high penetrations of PV, is currently trialling a Dynamic Export Limits scheme which they have coined Flexible Exports. The scheme offers consumers a choice between a higher flexible export limit (10kW per phase) or a lower fixed export limit (1.5kW per phase) when installing a new PV system.

When network constraints are binding, consumer's solar systems will be curtailed by sending them a new dynamic limit via an internet-based communications system.

Initial analysis on data gathered from the Flexible Exports trial indicates that for a typical residential consumer the Flexible Export limit will be at 10kW for the vast majority of the year, only limited below this value for 2% of daylight hours[1]. The results of this analysis are being publicly published and communicated to customers, which is key to showing consumers the value of such a system and in attaining community support and social license for the trial and planned state wide rollout of this scheme.

[1] https://www.sapowernetworks.com.au/industry/flexible-exports/faqs/

Figure 4: SA Power Networks Flexible Exports Architecture SOURCE: SA Power Networks



The Australian Energy Market Commission (AEMC) has recently passed a rule to allow for the recovery of export related network costs. This is a great start in providing a more cost reflective tariff structure and ensuring a more equitable outcome for all consumers, especially consumers who lack the means or opportunity to install PV systems.

The additional revenue generated through this revenue stream could be re-invested to further combat issues associated with minimum demand and increasing levels of non-dispatchable generation. It is up to DNSPs to propose a new tariff structure to the Regulator as part of their next reset submission (access arrangements) and have it approved before it can be implemented in a particular jurisdiction.

Many utilities have trialled grid scale storage over the last 5 years. Additionally, generators and other private companies have begun investing in large scale battery storage projects. For example, AGL is currently constructing a 250MW, one hour grid scale battery on Torrens Island in SA, with a planned completion date of early 2023. Batteries and other forms of storage will almost certainly be part of the solution to the minimum demand problem as they are able to soak up excess generation during the day and export that energy back into the grid when generation is required, provide synthetic inertia and have grid forming capabilities. The AGL batteries will have the ability to provide a fast response time of 100ms and the inverters being installed have grid forming capability, although this feature is not planned to be used immediately.

The decreasing minimum demand means that conventional synchronous thermal generation is slowly being squeezed out of the market during times of high PV generation. This results in lower amounts of system strength and inertia available connected to the system at these times. Inertia and system strength are required for system stability and to keep fault levels within the system at a reasonable level.

In South Australia, where low inertia has become a problem for system stability, the state's transmission company ElectraNet has just completed a project installing four large synchronous condensers in Davenport to help provide additional inertia and system strength meaning that less conventional synchronous generation is required for system stability. This means that only two conventional synchronous thermal generators are now required as a minimum at any time, meaning a larger amount of the state's energy mix can be provided by inverter-based technologies such as PV.

The examples mentioned show market players are undergoing a culture shift from a top-down to a collaborative approach. NSPs will need to adapt to this cultural shift at an accelerated pace and leadership will play a key role in driving the change in skills, systems and processes to drive the energy transformation.

There is vast knowledge and experience in managing the traditional networks and very limited experience to manage the assets and systems required in the future. Bridging this skills gap will be a determinant success factor for NSPs. The table below details the development areas required for different stakeholders.

Stakeholders	Development Areas
Government/ regulators	• Provide funding for new technologies. • Pioneer policy and regulatory changes • Develop systems that influence consumer behaviour in normal operating condition (e.g., export tariffs, variable tariffs)
Board, Executives and management/leaders	• Culture shift from conservative to disruptive • Promote innovation within business • Increase transparency and engagement of stakeholders
Human relations (recruitment and training)	• Understanding of the required skills and traits of the future workforce • Promote diversity and inclusion of people and skills • Implement training programs to match emerging technologies
Legal and compliance	• Understanding the legal boundaries of the relevant laws (e.g., privacy laws, Electricity Access Code) and new set of electricity relevant rules (e.g., NEM Rules, WEM Rules)
Professional institutes (IEEE, Engineers Australia, API, etc)	• Providing platforms for Continued professional development activities and information sharing towards the energy transition
Network planning and design	• Adapt to planning with generation from distribution e.g., aggregators, individual PVs, VPPs, Standalone power systems and synchronous generators • Design to cater for increased complexity of protection schemes
Network operations	• Shift from manual to automated operation for dynamic network conditions • Manage supply inputs from a more complex supply-chain including coordination of block loads
Field crew	• Upskilling to newer technologies and skills (e.g., less overhead rural lines, more standalone power stations) • Redeployment of workforce from traditional speciality roles to versatile roles
Information technology	• Create cyber security capabilities and data governance policies • Adapt to deal with big data and performing real time analysis • Incorporate artificial intelligence into BAU processes • Ensure compliance with privacy laws and handling data
Asset Strategy & management	• Developing strategies of incorporating older assets with emerging technologies • Management and monitoring of various types of assets • Management of risks associated with outages (increasing mitigation measures in order to secure outages)
Community engagement	• Education programs to align community understanding with service provider's energy perspectives towards a stable network • Collaboration with consumers on their investment return vs network stability decisions • Develop community's trust around data collection and privacy

3. Recommendations

This is an energy industry wide issue and it requires a coordinated effort from all players to deliver better outcomes for the broader community.

The following recommendations are informed by a range of presentations that

Network Service Providers (NSPs) will need to adapt to this cultural shift at an accelerated pace and leadership will play a key role in driving the change in skills, systems and processes to drive the energy transformation.

The following recommendations are targeted at NSPs; however, these will be more successful if accompanied by equally disruptive changes in how other market players operate and interact with each other. The grid operates as a system and will deliver the best outcomes when all the components of the system are aligned.

Strategic Recommendation 1: Understanding the consumers

As consumer choice increases and load profile changes, it is recommended that NSPs dedicate resources to understand consumer profile in more detail, to design fit for purpose solutions. NSPs should clearly define the data required to understand consumer preferences and profile and develop models to inform decisions.

It will require a step-change in Information and Communications Technology (ICT) investment to develop the capabilities and build complex models to understand consumer behaviours and expectations. Therefore, a staged approach is recommended. Currently available information can be used to develop first-generation models that can be enhanced as more information becomes available.

The key risks to consider when implementing strategic recommendation 1 are:

- Collect too much, insufficient or wrong data – define clear requirements for data collection and rules for data processing to produce actionable insights.
- Analysis paralysis – clear purpose and objective and acceptance of a greater level of uncertainty.
- Cybersecurity and privacy threats – follow applicable protocols for data protection and ensure a strong governance framework for systems and models.

The Energy Charter provides a framework and methodology to capture the "voice of the consumers" so that it can influence strategic decision-making and direction

Benefits:

Detailed understanding of consumer profile, expectations and experiences will allow NSPs to develop targeted strategies to avoid localised deterioration in performance and minimise the investment required to deliver the agreed outcomes.

The consumer engagement required to collect the data to develop the models will generate opportunities to facilitate the education about the services that NSPs provide and how consumers can benefit from the energy transformation.

Strategic Recommendation 2: Understanding NSPs' role

NSPs are increasingly transitioning from organizations that facilitate a one-way supply of energy to a facilitator of a complex energy market, with a major role in ensuring the network remains stable and strong enough to facilitate two-way energy transactions between generators and consumers.

Currently, tariffs don't reflect the network stabilisation services that NSPs provide to generators and costs of operating and maintaining the network are equally distributed amongst all consumers, including the ones that don't generate. NSPs should consider the following measures:

SR2.1 Structure services, assets and costs in line with the services provided.

SR2.2 Lobby Regulators to structure tariffs in accordance with services provided.

SR2.3 Lobby State Government to develop a Distributed Energy Resources (DER) roadmap.

SR2.4 Educate consumers about the energy transformation and the role of rooftop PV.

SR2.5 Educate the consumers about efficient use of electricity and how they can minimise consumption.

SR2.6 Develop user-friendly and interactive consumer interfaces.

SR2.7 Develop tailored communication with consumers channels for day-to-day and emergency works.

SR2.8 Proactive engagement with the media and social media.

The key risks to consider when implementing strategic recommendation 2 are:

- No agreement with Regulators or State Government on the proposed changes to regulations – NSPs must develop a value proposition that puts the electricity price in a sustainable trajectory for consumers with clear benefits in fairness and options tailored for a diverse consumer base.
- Low engagement from consumers – In engaging with consumers, NSPs must minimise the time of each engagement and clearly identify what the consumers stand to gain from engaging.

The Centre for Behavioural Economics, Society and Technology has evidence-based behavioural research that can inform NSPs' approach to consumer relationship management.

Benefits:

Strategic recommendation 2 is expected to allow for a fair distribution of the benefits of the energy transformation, a tariff structure that is better aligned with the services that NSPs provide and that better serve the consumers' needs.

It will increase consumers' choices, increase the awareness of the energy transformation and enable consumers to benefit from it.

It is also expected to deliver efficiencies in investment as NSPs would be structured in line with the services currently provided which will facilitate assessment and justification of the investment.

Strategic Recommendation 3: Managing the assets

NSPs are asset-intensive organizations and so asset management plays a crucial role in delivering the outcomes to stakeholders. To deal with the increased complexity, NSPs must enhance condition monitoring and data analytics to improve the understanding of asset condition. The following measures should be considered to the extent that the expenditure can be justified:

SR3.1 Clearly and objectively identify data that needs to be collected from the asset.

SR3.2 Roll-out online condition monitoring of critical assets and establish a platform for data analytics.

SR3.3 Quantify risk. Dedicate resources to ensure risk is quantified and comparable across different portfolios.

In close collaboration with planning engineers and operational teams, asset managers should:

SR3.4 Adapt to a consumer-centric view of asset management.

SR3.5 Define a future vision for all substations, lines and feeders in the network.

SR3.6 Develop replacement strategies aligned with the future vision of the network.

SR3.7 Define maintenance strategies that increase asset utilisation.

SR3.8 Understand integration of short and long-life span assets.

SR3.9 Progressively upgrade protection to enable the required functionalities in the network.

SR3.10 Reinforce the communications network to ensure it can support the increase in data transfer.

SR3.11 Adapt to identify and articulate the benefits of new technologies.

SR3.12 Explore the possibility to increase interconnectivity or reginal load transfers.

Asset management strategies should clearly define the strategic direction and the range of options to consider when making capex or opex decisions, as well as rules defining when to use each option.

The risks associated with strategic recommendation 3 are managed as part of the strategy development process.

Benefits:

Strategic recommendation 3 is expected to deliver efficiencies in investment as NSPs would be able to make smaller, targeted investments with higher benefits and avoid regrettable investment on the existing network.

It would optimise the data requirements, streamlining analytics and increase availability of engineers, technicians and asset managers for higher value tasks.

Strategic Recommendation 4: Operating the network

To increase asset utilization and avoid investing in assets that may sit idle during the minimum demand hours, it is recommended that NSPs engage with major consumers that have enough flexibility in their operations to allow them to increase load coinciding with the minimum demand hours of the day.

In order to adapt to manage a more unstable network, implementation of dynamic ratings supported by an increased level of automation is recommended.

The key risk to consider when implementing strategic recommendation 4 is:

- No agreement with consumers to influence the time of the day they draw load – develop commercial incentives to make this option more attractive.

Benefit:

By managing the demand, NSPs can minimise variations throughout the day, reducing the need to invest to maintain system stability.

Strategic Recommendation 5: Transforming the network

To minimise the impact of uncertainty around what the future network looks like, and lower the associated risks, the following measures are recommended for the NSPs:

SR5.1 Based on consumer profile enabled by strategic recommendation 1, establish trials to test new technologies and use the learning from the trials to define which solution is more appropriate for each asset type and geographical location. The following should be considered:

- Different methods of aggregation.
- Establish targeted virtual power plants.
- Deployment of targeted microgrids.
- Explore targeted network reinforcements to strengthen the network.
- Explore the use of synchronous condensers to provide network stability.
- Explore partnerships to install grid forming batteries.
- Explore the possibility of installing storage capacity at the distribution level (LV) in partnership with aggregators or residential consumers.
- Alternative energy storage methods, such as pump-hydro.
- Explore load banks as an emergency measure to increase load demand at short-notice .

Trials allow NSPs to test each solution and develop the criteria to use each solution. Knowledge sharing will be critical to minimise risks and costs across the industry with better outcomes for consumers.

The main risk with conducting a high number of trials is:

- Ensuring adequate governance and safety – develop a trial governance framework and ensure adherence to it.

Benefits:

The key benefit is to remove uncertainty and ensure future solutions are trialled before implemented.

It will also give NSPs the opportunity of upskilling the workforce and develop a pool of talent to manage the future network.

As NSPs work more closely together, they will be in a better position to drive the transformation and influence the stakeholders.

Strategic Recommendation 6: Delivering the transformation

Traditional NSP delivery is slow in managing the risks associated with minimum demand. It is recommended that NSPs streamline scoping and planning and minimise delivery costs. The following options are recommended:

SR6.1 Early procurement of long lead items.

SR6.2 Establish a panel of approved vendors that can deliver a comprehensive range of tasks.

SR6.3 Shift from a supply-chain (vendor/customer) relationship to establishing partnerships leveraging cross-functional and cross-organizational teams working together.

SR6.4 Streamline internal approval processes.

SR6.5 Deliver complex projects in stages; and apply lessons learned from earlier stages to improve delivery of the later stages.

SR6.6 Establish a dedicated team to drive delivery cost reductions.

The risks associated with strategic recommendation 6 are managed as part of the delivery process.

Benefit:

Delivery cost reduction will have a direct impact on NSPs cost reduction.

Authors

Frederico is an industrial engineer with 20 years' experience in a broad range of industries including Defence, Rail, Medical with a focus on the Energy sector for the last 10 years. Frederico first joined Western Power during the Parliamentary Inquiry into wood poles management and was part of the team that changed the way Western Power manages asset criticality and performance. In his current role as an engineering team leader, he manages a team of senior engineers accountable for developing asset management strategies for transmission assets and is currently acting manager for both distribution and transmission asset management strategies. His experience in the sector also includes trials of new condition monitoring technologies, risk management, connection of major loads and generation to the network. Linkedin contact - Frederico Rego

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Pep has 14 years' experience in the Power sector made up of practical field experience as well as engineering experience. She is a holder of a Beng (Hons) in Electrical Power and Renewable Energy Engineering. She is experienced in substation maintenance, interpretation of standards to influence design decisions, Overhead and Underground design, Earthing, Customer Focus, Stakeholder Engagement and Leadership. Pep is a volunteer STEM mentor who seeks to inspire an interest in STEM at grassroots level. She currently leads a team of engineers in the Network Distribution Design and Customer Connections space in Western Power. Linkedin contact - Pep-Ngwenya