Connecting EV charging stations to distribution networks

Electric vehicles thought leadership

Growth Unit Network Energy Storage

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Executive summary

The rise of electric vehicles (EVs) represents a fundamental change to global transport systems, which have predominantly relied on petroleum-based liquid fuels from the late 19th century to the present day.

This shift away from petroleum fuels to electricity will revolutionize how societies access and consume energy. And as electricity powers a larger share of global transport energy demand, there will be greater dependence on aging distribution grids.

Electric utilities will need to respond to the changing profile of electricity demand. Some of the challenges they will face include how to fund and upgrade distribution networks, coping with intensive demand from fast chargers, how to approach emerging Vehicle-to-X pathways, and catering to different approaches to electricity distribution across the world.

We will identify possible solutions to these challenges to both manage the growing demand on distribution grids and upgrade them where necessary. These solutions aim to enable the rapid uptake of EVs all over the world and reduce fossil fuel consumption from passenger cars, lowering global greenhouse gas emissions.

1 The rise of electromobility

Electric vehicles (EVs) are becoming increasingly popular. According to BloombergNEF's Long-Term Electric Vehicle Outlook 2021, they could represent 70 percent of new passenger car sales by 2040 globally and comprise almost half of all cars on the road within two decades. This uptake is anticipated to continue, with several countries in the European Union (EU) and the United Kingdom (UK) aiming to phase out petrol and diesel cars in the coming decades.

As EVs become more prevalent, there will be an increasing need for EV charging infrastructure. However, this presents a challenge for the distribution grid, as the EV charging process can place a large and sudden demand on the system. This can cause problems for a distribution grid that is not designed to meet this demand, potentially leading to voltage unbalance[1] or blackouts.

To avoid these issues, upgrades will be needed to reinforce the grid and make it more resilient. In addition, new policies or pricing structures may be required to encourage EV owners to charge their vehicles during off-peak hours. Otherwise, the EV boom could end up putting even more strain on the distribution grid.

2 Emerging challenges for electric utilities

Distribution grids were not designed to handle large numbers of EVs charging at the same time. This can cause problems ranging from localized power outages to voltage fluctuations that can damage sensitive equipment.

As a result, electric utilities must seek innovation or make significant upgrades to the distribution grid - an expensive and time-consuming process. In addition, electric utilities must grapple with the fact that EVs can act as 'mobile batteries,' storing electricity when demand is low and releasing it when demand is high. This can create new challenges for electric utilities, which are used to managing a relatively stable flow of electricity. Ultimately, the success of the EV revolution depends on electric utilities' ability to upgrade their distribution grids – a task that will require significant investment, planning and innovation.

From conversations with our customers across various regions of ANZ, EMEA and the Americas, concerns from the EV infrastructure proponents and Distribution Network Service Providers (DNSPs) are very similar. Typically, grids across the world have been designed for one way electricity supply and have not considered Distributed Energy Resource (DER) technologies.

Now, with forthcoming EVs capable of supplying electricity back to the grid (this is commonly referred to as Vehicle-to-X (V2X) as 'X' may be the grid (V2G), a home (V2H) or any other electrical load (V2L)), new challenges and opportunities are emerging for grid operators.

[1] https://link.springer.com/article/10.1007/s40903-015-0005-x

3 The changing profile of electricity demand

Globally, increased EV demand will stress the capacity of electricity grids, particularly for distribution grids that are already under seasonal stress from the electrification of household heating and cooling.

This creates a universal issue for DNSPs and the growth of electrification as a solution to decarbonization. Transmission Network Service Providers (TNSPs) will also be impacted by the increase in the demand for large scale renewable energy required to support the increased demand for green electricity to support the transportation sector.

The two greatest challenges facing the grid operators with the rise of EVs is the amount of electricity required to decarbonize the transport sector, and time of day at which charging occurs. A destabilizing impact to the network will be from thousands, or even millions, of EVs attempting to charge simultaneously – an 'unmanaged charging' scenario. The more vehicles that connect to conventional electrical networks, the greater the risk to the adequacy, reliability, and quality of power supply. This can lead to voltage drops, voltage fluctuations and power losses.

As an example, if virtually all passenger cars in Texas were electrified today, the state would need approximately 110 more terawatt-hours of electricity per year, the average annual electricity consumption of 11 million homes. The added electricity demand would result in a 30 percent increase over current consumption in Texas and will test the state's ability to produce enough clean energy, in addition to its ability to supply clean energy to users in areas where there may already be system constrained[2].

Similarly revealing research from Canterbury University suggests that if 100 percent of the vehicles were electric in New Zealand, somewhere between 8.1 to 9 GW will be needed to charge them all at the same time[3].

At present, globally, there are many reports of DNSPs that have experienced challenges associated with large volumes of EVs being connected and charged from their network. These EV related network concerns are:

- **Exceed network design limits**

  Extra demand (from EVs) could exceed network design limits. Potential EV related network constraints and power quality issues will first start to emerge on the low voltage networks.

- **Limit EV hosting capacity**

  The constrained or weak parts of the network will be most affected. Their ability to host EVs (EV hosting capacity) becomes increasingly more difficult with the main limiting factor being equipment, particularly, the low voltage (LV) distribution transformers.

- **Potential shift in peak demand**

  The peak time for most networks is 6 pm – 8 pm. If consumers were to plug in their EV chargers around this peak time, this will be problematic for networks as there will be a significant energy demand increase at an already congested time.

[2] https://www.powermag.com/driving-change-on-the-grid-the-impact-of-ev-adoption/
[3] https://www.standards.govt.nz/get-standards/sponsored-standards/electric-vehicle-ev-chargers-for-residential-use/

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There is the potential for a second peak. If EVs were to charge when prices are low (overnight until early morning) and on time of use tariff, there might be a case of a second peak. Given the lack of solar energy in the system at this time, a heavy reliance will be put on other forms of low carbon generation, including wind, nuclear, natural gas or biofuels, geothermal hydroelectricity, as well as the need for long-duration grid connected storage.

- **Sub-optimized charger technology/location**

  Lack of transparency about where and when proponents may wish to locate new EV infrastructure and general uncertainty about the timing, capacity, and scale of the charging infrastructure. DNSPs can make educated guesses, but they can't know for sure which parts of the network will be stressed, and to what degree, while proponents are only able to install chargers that align with the available capacity in the network, rather than installing the best available technology at their preferred strategic locations.

- **Network visibility issues**

  Some network operators have limited visibility on what is happening on the customer side of the network with relatively low visibility of transformer loads and voltage constraints on the LV network, compounded by low visibility of EV charger impacts.

- **Under/Over-utilization of networks**

  The reverse challenge may also present itself from a potential under-utilization of networks that have been strengthened to cope with anticipated charging patterns that may not eventuate.

  These challenges are likely to be compounded by growing congestion in electricity grids all over the world due to electrification to meet NetZero targets. Below are some examples.

- Motorbikes are taking over as the preferred forms of transport in many parts of Asia, with sales forecast to more than double from USD $15.73 billion in 2020 up until 2030, when they're expected at around USD $30.52 billion. It is anticipated that this will create extraordinary pressure on grids which already suffer from congestion and renewable energy curtailment.
- The UK is experiencing an increasingly complex energy landscape. With EV penetration estimated to reach 50 percent by 2040, network voltage deviations go beyond the standard level and for that reason a "fit-and-forget" approach to charger connections risk further increasing congestion in already overtaxed networks. This issue is anticipated to be more complex at the end of the typical working day when EV owners return home and commence charging which coincides with typical evening peak grid demands.
- In Europe, industry analysis has demonstrated that some scenarios, such as peak loads, will increase from 21 percent to 90 percent in urban areas in 2035. Transformers, in most cases, will have to operate above their rated capacity[4].

[4] https://www.ey.com/en_hu/energy-resources/as-emobility-accelerates-can-utilities-move-evs-into-the-fast-lane

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4 Challenges of connecting EV charging stations to distribution networks

4.1 The availability of public charging points

The adoption of public charging points in Europe is patchy, with urban centers containing most of the public charger stock. Urban users also suffer from finding convenient charging locations, with a lack of off-street parking creating significant demand for on-street chargers in residential zones in cities.

In the UK, approximately 30 percent of homes do not have driveways where chargers can be installed. That rises to 70 percent in the Netherlands and will drive the demand for higher powered fast chargers and increase demand on local networks.

4.2 EV charger types

There are various types of EV chargers and different locations where they can be installed. Home charging is likely to be most popular due to charging overnight while sleeping, and in this setting, slower charging (> 8 hours depending on the size of the battery) is usually acceptable. In offices, apartments, universities and shopping centers, charging stations would typically have to be mid-range charging (1/2 to 8 hours). And on the highway at specific EV charging stations, drivers require fast charging.

Fast chargers will enable EVs to be charged in less than 30 minutes. However, this will put the most pressure on the grid, especially if the EV charger is to be connected to a constrained network, and hence networks will not be able to accept new EV connections. In Australia, it was found that urban feeders can have larger EV hosting capacity than rural feeders as larger numbers and smaller size of LV transformers used in rural feeders result in many congested transformers with low EV penetrations[5].

The right type of EV charger for grid connection is crucial. If EVs were to support the network at peak times (V2G capability), then bi-directional capability must be considered. Most EVs come with a basic charger but can be upgraded to operate on both single phase and three phase supply to suit the grid connection.

4.3 Connection process

The EV connection to the grid process is not clear enough. At present in Australia, appropriate industry standards that EV chargers must comply to are AS4777.2.2020[6]. The network connection process for both private and public EV charging stations needs to be differentiated to ensure time efficiency before mass volumes of EVs start to enter the market.

In the UK, domestic wiring in homes is inconsistent with configurations in British wiring regulations and requires considerations when installing an EV charging point on driveways. The concern is whether

[5] https://www.researchgate.net/publication/361023863_Assessing_the_Unmanaged_EV_Hosting_Capacity_of_Australian_Rural_and_Urban_Distribution_Networks
[6] https://arena.gov.au/assets/2022/03/case-study-grid-performance-of-a-v2g-capable-ev-charger.pdf

they can handle the energy requirements of an EV charging at the same time as other household appliances simultaneously in use[7].

A challenge for vehicle manufacturers and charging infrastructure providers alike is that the European network of public charge points is not expanding fast enough. There are three principal reasons why:

1. **Local government permitting delays and access to available real estate**
   Local authorities often lack dedicated teams to administer the review of public policy and town planning/building permit applications associated with the rollout of EV charge points and are becoming overwhelmed with the number of proponents entering the market. It can take months for charge point operators, responsible for installing and maintaining charging stations, to get permission to sight their infrastructure.
2. **Delays and costs in obtaining a grid connection**
   Anecdotally, some industry leaders reveal that charge point operators in some European countries can wait up to 36 months to get a connection. Significant local bottlenecks are commonplace, especially where grid upgrades are needed to accommodate hubs of rapid and high-powered chargers. There are also questions about who pays for grid connections, as well as policy options for funding public chargers.
3. **Lack of interoperability between charger networks**
   Using a charge point is not as straightforward as filling up with fuel. Lack of interoperability, due in large part to an absence of common standards, restricts user choice about where to charge and how to pay. Meanwhile, poor reliability on some networks, and variable levels of customer service, add to driver frustration.

4.4 Data provision

Data provision from networks can be a challenge to enable EV studies, especially when it comes to network data and consumer data privacy. Japan and the state of Victoria (Australia) has 99 percent penetration of smart meter data for use in EV studies, but other states and countries do not have this capability. Lack of data from networks will deter network visibility to carry out future EV studies. The more network visibility, the easier it will be for networks to enable EV connections into their networks as they will be able to identify which areas of the networks would be suitable for EV connection.

An ideal scenario would be if DNSPs have full visibility of their networks and can provide transparent data / network maps that shows areas / zones with high EV hosting capacity.

[7] https://versinetic.com/tacking-grid-challenges-to-ensure-the-success-of-evs/

5 Collaborating to build EV infrastructure at scale

The EV infrastructure issue does not just relate to transmission line capacity or power systems. It also requires social, policy, economics, town planning, civil engineers, and data scientists to deliver and operate, hence a diverse background of people is needed on both the developer and DNSPs teams to work on EV charging and connections.

DNSPs around the world are aware that EVs are coming and are now thinking of making the networks ready through network (infrastructure upgrade) and non-network solutions. The addition of new 'dynamic loads' will create the need for infrastructure upgrades, distribution lines, residential substations and transformers, and switchgear will need to be considered. DNSPs don't know how fast the EV market is going to grow, nor how the capabilities of these vehicles are going to develop.

5.1 Differing approaches/readiness around the world

Large DNSPs such as EDF, E.ON, and Enel in Europe have been investing in EV charging station infrastructure, and increasingly, are collaborating with EV manufacturers to boost their offerings in areas such as EV charging, vehicle-to-grid (V2G) services, energy storage, and renewable energy sources.

In the USA, Southern California Edison (SCE) is among one of the proactive DNSPs when it comes to incorporating EVs into their network planning. DNSPs in California and Texas are using data to monitor, track and predict energy usage for EV studies. The need for grid upgrades in the USA will vary by region and depend on the existing grid capacity and utilization rate of EV growth.

Japan is also planning to expand its network by high voltage direct current (HVDC) lines and upgrade the traditionally weak interconnections between the 10 EPCO (Electric Power Companies) service zones[8].

In Australia, finding the right person who works on EVs or connections can be a challenge as EV connection standards are not clear enough. However, in countries such as New Zealand[9] and China, this process is more developed and streamlined.

5.2 Vehicle-to-X

For DNSPs, Vehicle-to-X which comprises Vehicle-to-Grid, Vehicle-to-Load or Vehicle-to-Home, provides and facilitates a solution to the energy fluctuation due to the high share of renewable energy, as well as the solution to the grid congestion and circumvents the need to upgrade the grid infrastructure. For the aggregator/EV operator, V2X presents a new business opportunity in the electricity sector, including grid balancing services (in correlation with utilities, grid operators, and consumers) and renewable energy storage services (e.g. storage and minimization of curtailment and fluctuation).

In Australia, DNSPs are performing trials to test demand response capability using EV charging infrastructure, where customers are rewarded for their participation (home charging only)[10]. This

[8] https://epub.wupperinst.org/frontdoor/deliver/index/docId/7425/file/7425_Smart_Power_Grids.pdf
[9] https://www.nzta.govt.nz/planning-and-investment/planning/transport-planning/planning-for-electric-vehicles/guidance-for-ev-charging-infrastructure/
[10] https://www.evgrid.com.au/

includes conducting trials to better understand customer behavior and the changing needs of customers to determine the best way to integrate EVs into the network and provide convenient and affordable access to electric vehicle charging[11].

6 How to address these challenges

If the dynamic nature of EV drivers' behavior is unregulated, the existing grid infrastructure must be expanded, reinforced, and digitized. The following solutions could enable distribution grids to handle greater EV uptake:

- **Economic impediments or incentives**
  Such as time of use tariffs or other surcharges during peak charging periods or offering cheap or free electricity at time when there is surplus energy in the network.
- **Planning the rollout of renewable energy generation to match the demand from EVs**
  This will require a detailed supply chain analysis, involving renewable energy developers, TNSPs, DNSPs, EV charging infrastructure developers and regulators.
- **Regulators and EV industry representatives**
  Representatives who represent the owners and operators of commercial EV charging stations should co-develop standards, policies, processes, and engagement channels to assist business in decreasing the complexity of the grid connection process, thereby accelerating the deployment of EV charging infrastructure to their customers.
- **Detailed investigations into V2G technology**
  Regulators and network operators could commence detailed investigations into V2G technology and how EVs can best integrate with local solar (and battery) generation and support load management during peak daytime solar generation and evening peak demand.
- **Upgrade distribution transformers with monitoring and intelligence**
  Upgrading distribution transformers to incorporate monitoring and intelligence systems can inform the DNSP operator how much load was currently at that node on the network. Once this data is analyzed, the DNSP could work with EV charging infrastructure owners on the system to better manage user behavior in the area.

[11] https://www.tasnetworks.com.au/poles-and-wires/planning-and-developments/electric-vehicles

7 Enabling the rise of electromobility

The unregulated EV charging process can place a large and sudden demand on distribution grids that are not designed to meet this demand.

The challenges for the distribution network regarding EVs are availability of public charging points, multiple EV charger types, the lengthy connection process, and lack of transparency to consumer preference data. There needs to be a focus on working with the DNSPs to address these challenges and work collaboratively with many stakeholders. Upgrades will be needed to reinforce the grid and make it more resilient.

New policies and pricing structures will be required to encourage EV owners to charge their vehicles during off-peak hours. Otherwise, the benefits of the EV boom could be negated by regular blackouts and grid instability.

Contact details

Nicole Wright

Growth Unit Network Energy Storage – ANZ Lead

nicole.wright@advisian.com

advisian.com