Issue #80 - Spring 2018

Technical News

Specialists in electrical and automation products, systems and solutions

Electric Vehicle Infrastructure Design Considerations

Providing solutions for load management, billing and data reporting associated with EV charging equipment in commercial buildings and apartment complexes.

Written by Ross De Rango
Product Development Manager - Integration and Technology, NHP

INTRODUCTION

Load balancing, billing, and data reporting are common challenges that are raised when Electric Vehicle (EV) charging is proposed for installation.

With the recent update to the wiring rules (AS/NZS 3000:2018 Appendix P), it is suggested that a maximum demand calculation should assume that all EV chargers are operating simultaneously at full load. This is readily achievable for a small number of chargers at large sites, but for a large number of chargers, this assumption will imply costly upgrades to site capacity.
A smart load management solution for apartment complexes and commercial buildings, designed to ensure that the EV charging load does not 'stack' with existing peak building load, is necessary if we are to avoid significantly increasing the size of site connections, transformers, and switchboards.

Billing for electricity supplied is also a consideration for EV charging installations, but one with many solutions. In some cases, billing will not be required, as the value of the energy being delivered is trivial in the context of the location. For cases where billing is necessary, there are many options.

Data reporting can also be done in many ways. Data reporting will allow for facility managers and other interested and authorised parties to see usage behaviour, which can help with forward planning, and maintenance.

In this Technical News, we will examine several options around load balancing, billing and data reporting specifically in the context of Electric Vehicle charging infrastructure.

Figure 1: Delta AC Mini Plus

*This document is written in accordance to Australian regulations, New Zealand and other jurisdictions may vary in standards and will require differing methods.

AVAILABLE METHODS FOR LOAD MANAGEMENT

No Load Management

In cases where a small number of AC chargers are being installed in a commercial premise, load management will typically not be required, unless the switchboard is already routinely overloaded. A review of historical interval data should enable determination on this point.

Installations of AC EV chargers in commercial premises today are typically handled in an unmanaged fashion, because most installations today are 'ones and twos' of units in the 7kW peak range.

However, as the transition to electric vehicles ramps up, this will not be a viable approach. Using NHP's head office as an example, we have a 1200A main incomer, and up to 150 vehicles on site each day in the car park. If we assume a future where 100 of these vehicles are plug-in electric, and that employees turn up between 7:30 and 8:30, plug in, and draw on the average about 5kW for an hour or two, we would have a new load of ~500kW presented to the main switchboard. On hot summer days when the night time temperature has stayed above 25C, the air conditioning is already operating at 8am, there is not always 500kW of headroom available to be used.

Apartment complexes will present an even more significant problem. People will typically plug in when they arrive home. Without any load management in place to defer charging until later in the evening and spread the load throughout the night, the vehicles will start charging immediately, for a typical period of an hour or two. This timing will coincide with peak demand, both on the grid and within the local infrastructure, on hot summer afternoons. In the future, apartment complexes will either need some form of load management for EV charging, or they will need to drastically increase the size of their main switchboard and the infrastructure that supports that switchboard (typically the transformer in the street).

An important point to make here is on the subject of diversity, which in the electrical context means the degree to which electrical loads in a building consume energy at the same time. The wiring rules have recently been updated to include informative guidance around electric vehicles (AS/NZS 3000:2018 Appendix P) assuming that all EV charging equipment installed runs at full capacity all the time. So, for example, an installation of 100 x 7kW chargers in an apartment complex basement should be assumed for the purposes of electrical design to present a continuous 700kW load to the upstream supply.

The practical effect of following this guidance is that the site connection, transformer, switchboard, and distribution boards will all end up sized and designed significantly larger, at a substantial additional cost to either the developer (in the case of new builds) or the body corporate (in the case of upgrades to existing apartment complex stock).

The first observation to this point is that this would be a reasonable design philosophy in the absence of smart load management in an apartment complex, since most EV charging loads could reasonably be expected to coincide with peak air-conditioning loads on hot summer weekday afternoons when everyone gets home from work.

The second observation is that it if smart load management is implemented, substantial additional cost can be avoided. If we assume that:

- The EV charging load is spread across 12 hours
- The 100 drivers in the example above do an average of 50km of driving per day
- They do not charge at their workplaces,

then the actual average load is more like 80kW, not 700kW. If we compress the charging time into the period from 11pm to 7am, when air-conditioning load is minimised, the average load presented is around 125kW. Loading at this level at this time of day is unlikely to require a network connection, switchboard, or transformer any larger than the apartment complex would have installed already to service the existing peak demand.

Electrical Load Management

The most basic way to do load management for an application of this nature would be to place energy metering with low-level communication capabilities (Modbus over RS485, for example) on the main incomer to the switchboard and on the moulded case breakers upstream of the EV chargers, and contactors upstream of the EV chargers. A simple program in a low-end PLC would then be able to figure out in real-time what electrical energy the building is consuming, and how much headroom there is to support EV charging. The PLC would then open contactors upstream of the EV chargers as required to keep the total building load within acceptable limits.

This approach is simple to implement and would work perfectly from a pure load management perspective, but it will not meet the expectations of electric vehicle owners. Turning the power off mid charge with no warning is not great for the battery in the vehicle and will in some cases result in the vehicle setting off an alert or alarm. This may take the form of a message on the in-vehicle display, or it may be more like a car alarm or an automated notification to the driver's phone.

There is also the issue that depending on the specific vehicle charger and the specific vehicle, closing the contactor again may not automatically restart the charging process. The car owner may be required to manually press a reset button physically located on the charger, for example, which will not be convenient overnight.

On this basis, NHP does not recommend this approach as a primary method to achieve load management.

Where this solution may be appropriate would be as a back-up method to other solutions employed for the load management task. For example, if a cloud-based billing and authentication system is being used to perform load management, its performance will be compromised whenever communication between the EV charger and the cloud-based server performing the system control is lost. The weakest link in the system is the local telecommunications infrastructure – even the most reliable cellular networks in Australia are offline once or twice each year in some regions.

An implementation of electrical load management in combination with cloud-based management could be set up such that the contactors would only open in the event that conditions indicating requirement for load shedding have been met, and the load has not actually been shed by the cloud-based system. The contactors shedding the load would be the last line of defence before the medium and large circuit breakers at the site started tripping, cutting both the EV charging loads and potentially other loads at the site.

Local Smart Load Management

To avoid negatively impacting the batteries in the vehicles, the load management system needs to communicate with the charger, which is in communication with the in-vehicle charge controller, and define a lower maximum charging rate. For example, if the charger is capable of delivering 7kW, the load management system might instruct it to reduce its peak allowable draw to 1 or 2 kW for a period of a couple of hours, while other loads in the building are high.

The standard protocol that EV charging equipment uses is OCPP, which is primarily designed for cloud-based billing and authentication, but can also be used for load management. In cases where billing and authentication are not required (see 'No Billing Systems/ Indirect Billing' and 'Billing for site access, not for the usage'), this protocol could be used locally over EtherNet to the charging equipment, either via CAT5 cable or WiFi.

This approach is similar to the electrical load management approach described above, in that the energy meters would read the real-time usage of energy in the building, and a small smart controller would then compute the available headroom for EV chargers. The key functional difference is that instead of taking chargers offline with a contactor (either individually or in groups), the smart controller communicates with the network of chargers via a gateway to command a reduced charging rate, or stop the charging process in a managed way.

This solution is better for the vehicle batteries, and will allow for much better control over energy in the building. Importantly, this is a solution which is purely local in its execution. There is no requirement for an internet connection, or an ongoing cloud-based service subscription.

It is also vendor agnostic, from the point of view of the EV charging equipment and upstream power distribution hardware involved.

It should be noted that a smart system like this one cannot readily co-exist with a cloud-based authentication and billing system, or with an externally managed demand response system. Two or three different systems all trying to track and modify the charging behaviour in real-time, without coordinating with each other, will not work.

System integrators and building automation contractors will be able to customise system behaviours for individual sites. There may be a desire to prioritise charging in certain parking locations, for example, or have an override control in place to start charging immediately if required.

Cloud-Based Load Management (Incorporating billing, authentication, and reporting)

Systems enabling EV chargers to communicate with cloud-based software have been developed around the world to enable user authentication and billing. These systems typically involve apps that can be downloaded to the smart phone of the EV owner, with the EV owner's credit card details stored by the operator or an associated third party for billing purposes, much like Uber.

Some of these are proprietary to specific types of charging equipment, or to specific energy companies, but increasingly we are seeing open systems which will support any EV charger supporting an up to date OCPP protocol.

While the primary purpose of these systems is billing and authentication, the fact that these systems take a degree of control over the charging process means that making them co-exist with other smart load management systems is challenging, as noted above.

For this reason, systems of this nature commonly offer the capability to perform load management as well. In cases where a cloud-based billing and authentication system is being used, primary load management from that system, backed up by an electrical load management system designed to open contactors at a slightly higher threshold in the event of loss of communications or any other failure on the part of the cloud-based system, is considered by NHP to be acceptable practice.

Pricing for this style of cloud-based software management solution in the Australian market (at the time of writing) is on the order of $350- $400 per year per EV charging station, handled as a subscription/contract service.

Figure 2

WHAT METHODS ARE AVAILABLE TO PROVIDE BILLING FOR EV CHARGING

No Billing Systems/Indirect Billing

The next question after ‘how do we supply the power?’ is typically ‘who pays?’ There are many examples of cases where no special arrangements need to be made for billing, some of the more common ones are given below.

In a typical Australian household, the EV charger in the garage or carport can be supplied from the load centre in the house, downstream of the household utility meter. This means that the householder will simply see the cost of the electricity used to top up the battery in their car overnight in their usual electricity bill. So, no special arrangements for billing are necessary.

It is becoming more common in retail locations around the world to provide AC EV charging in customer car parks at no direct cost to the driver, to attract the electric vehicle owner to the shopping centre in the first place, and to then increase the amount of time the driver spends in the shopping centre. No special arrangements for billing are necessary in this case either; the assumption is that the cost of electricity to the site operator will be greatly outweighed by the additional spend in store.

It is worth noting here, that the typical cost of electricity to a shopping centre is around 10c/kWh. Using a vehicle such as an Outlander Plug-In Hybrid as an example, the electricity cost to the shopping centre while the vehicle is charging will be around 35c/hour. By selecting charging equipment with a suitable maximum charging rate, the cost exposure can be directly controlled.

Workplaces are another example where no special arrangements are needed. Access to the car park is typically restricted to employees and visitors, to whom provision of EV charging is provided either as a cost saving measure (in the cases of fleet vehicles operated by the employer, displacing their petrol/diesel costs) or as a perk to employees and visitors to the workplace driving electric vehicles.

Local and state governments are also offering public charging at no cost to the driver in many cases at present, while retaining the right to bill for usage in the future. The rationale behind this is that the total cost of electricity used per annum by the charging equipment is presently a tiny fraction of the equipment installation cost (i.e., <1%), and their interests will be best served by supporting uptake of electric vehicles more broadly, rather than attempting cost recovery at this stage on the energy consumed.

For example, in regional areas part of the rationale for local government installing 'free' EV charging is to support their local business owners. EV drivers stopping in a council-operated parking space for an hour or so to top up their battery 'for free' will have lunch at a local eatery, and potentially shop at local stores, rather than simply driving straight through to the next town or destination.

Billing for site access, not for the usage

As mentioned, there are specific cases where direct billing or cost allocation in some form is appropriate and necessary.

In some cases, a new technology approach will be used to meet these needs, but there are existing methods that can be applied as well. This section focusses on using existing methods around billing for the provision of car parking spaces, and on administrative cost collection methods that do not require handling the supply of electricity as a transaction.

Locations where parking is already being paid for, have a clear pathway towards cost recovery of the electricity, by increasing the price paid for parking. In Melbourne and Sydney CBDs, the cost of occasional parking is routinely well above $10/hour.

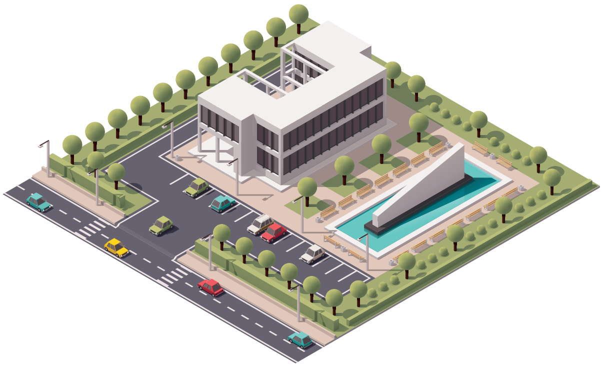
Incrementing the cost to account for supply of electricity in these cases will be an almost insignificant addition, and the hardware required to support charging at rates around 7kW (i.e., adding up to 40km of range per hour parked) is not particularly expensive. The justification for the car parking operator to install the equipment is in the attraction of the EV driver to their car park. Any collection of revenue from the supply of electricity is incidental from the point of view of the car parking operator; the point is to bring in the customer for the primary, high value service.

In apartment complexes where it is practical, the easiest way to provide for billing the right person for the energy used will be to supply the EV charger at an allocated car parking space via the same utility meter feeding the apartment to which the space is allocated. Depending on the installation, this might be very easy to do. For example, it is commonplace in some areas to have a utility metering panel containing all the complexes utility meters in the basement, with the downstream side of each meter running to the apartment. What is proposed here, is that in addition to the supply to the apartment, the metered supply should also connect to an EV charger in the car parking space, by way of suitable circuit protection.

This said, in some cases it may not be practical to wire the vehicle charging equipment this way. Installing additional metering for the EV chargers is certainly an option (which is covered in the next section), but it is also possible to incorporate the costs into body corporate fees.

As an example, in an average apartment complex in South East Queensland, body corporate fees amount to $5,000-$6,000/year. Adding an additional $500/year for owners who routinely park electric vehicles in the car park, where those vehicle chargers draw power from the same supply feeding common areas, will typically:

1) Cover the cost of the electricity supplied
2) Be perceived as 'fair' by other owners who drive traditional vehicles (i.e., 'no free lunch')
3) Provide the fuel cost-saving that the electric vehicle owner is looking for over petrol
4) Not require the installation of any special metering equipment
5) Not require an ongoing subscription to authentication / monitoring / billing services



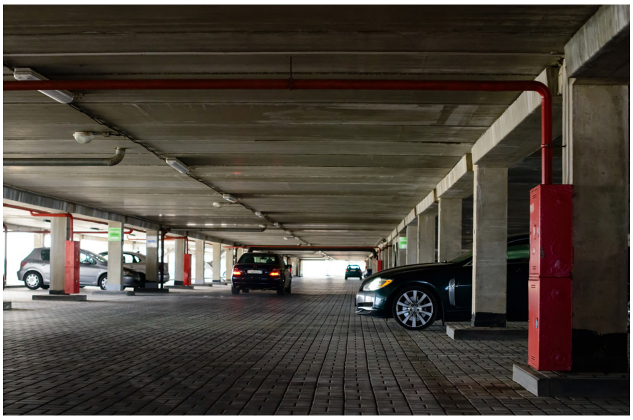
In workplaces where the employer is looking to attribute the cost of energy supplied to the EV driving employee, a very similar rationale can be applied, with the variation that instead of a fee being levied, it is factored in to the employee's contract. From a practical standpoint, if we assume a commercial electricity contract at ~10c/kWh and an employee with their own electric vehicle with a ~50km round trip to work, spending ~200 days/year at the office, the employer will be exposed to something like $200/year in vehicle charging costs if the employee chooses not to charge their car at home during the week. This could be readily recovered in the form of a contribution from their pay check on the order of $4/week, plus perhaps a small amount to contribute to the depreciation of the AC chargers installed in the company car park.

Direct billing via an Embedded Network

If the models covered above are not suitable or sufficient, consideration can be given to an embedded network.

Embedded networks are already very common in commercial developments, where there is a single large network connection to a traditional energy retailer, and the cost allocation to individual energy users below that level is handled by a non-traditional retailer, known as an Embedded Network Operator (ENO).

The rules governing embedded networks vary by state, and are undergoing change at present due to the recent 'power of choice' reforms, but in most areas in Australia the basic requirement is to provide a National Measurement Institute (NMI) trade approved energy meter at each point where a measurement is going to be made to determine how much a consumer should be charged for energy consumption. The primary intent around the meters being certified and approved is to ensure that a sufficiently accurate measurement is made so that the consumer is being billed accurately for energy consumed.



In cases where an embedded network is already being used at the site, adding additional scope to the embedded network to cover the EV charging equipment may offer a lower cost solution than a dedicated cloud-based EV charging management offering. It will also typically provide for portability in the event that the consumer wishes to change service providers, as there are many ENOs capable of taking on the provision of this service once the standardised equipment is in place.

From a practical standpoint, what this would look like would be fitting a distribution board upstream of the EV chargers with an NMI meter per EV charger, and then enabling an ENO to connect to those meters and using the data for billing. As a side benefit, the presence of individual metering will permit very granular data reporting, either by the ENO, or by another system reading the same data.

Transactional Cloud-based Billing

The most 'turn-key' of options for billing is to enable the EV chargers to connect to the internet, where a cloud-based service manages the authentication of the users through a smartphone app, and handles billing to the consumer's credit card.

The basic requirements of this approach are that:

1) The EV chargers need to be smart enough to provide data and be remotely controlled
    a. Noting that most EV charging equipment vendors have products that will meet this requirement
2) Reliable communications (typically via cellular data plans) are required
    a. Noting that this should be validated, especially in the case of basement car parks
3) The EV driver has a smart phone and a credit card.

Assuming the box can be ticked for each of the above points, solutions of this nature are available in the market, typically at a cost of around $350-$400 per EV charger per year.

It should also be noted that if a solution of this kind is being implemented, it should be capable of providing smart load management as well as billing, drawing input from either energy meters on-site or the local building management system, as an independent smart load management system will not typically co-exist easily with a solution of this type. NHP also recommends consideration of a 'back-up' electrical load management system in conjunction with solutions of this kind, so that in the event of loss of communications, the overall building load profile is not compromised. See the 'Electrical Load Management' section of this article for detail.

As this is a very new area, it is not yet clear how issues like vendor-lock-in are going to be managed. For example, if a charging equipment installation is procured from a vendor who also provides the cloud-based billing system, one question that should be asked is how readily an alternative billing solution provider could take over the service provision, in the event of the customer looking to change providers, or the original supplier going out of business. It is issues very much like this that prompted the power of choice reviews of the embedded network space in 2012.

WHAT OPTIONS ARE AVAILABLE FOR DATA REPORTING

No Data Reporting

Depending on the implementation, specialised data reporting requirements might be non-existent, or might already be captured via another system. For example, in the context of a domestic home with an EV charger, or an apartment dweller with an EV charger on an embedded network, the data provided on their regular bill might be sufficient. This will especially be the case in places with smart meters, where most consumers already have access to live and historical energy use data on their smart phones.

In a workplace, for the first one or two EV chargers installed, it may be sufficient to the site owner's expectations that they work. He or she may not be interested in the data, provided the hardware itself is operational.

The above said, in many cases in commercial implementations, there will be a desire to see usage patterns of the EV charging equipment, either as a proxy for cost, or to establish whether there is need to expand the amount of EV charging equipment available at the site. Note that these requirements are distinct from data collection for load management and billing, but that systems designed to perform load management and billing will often be able to perform data reporting at a reasonably granular level as a by-product of their core function.

Assuming billing and load management solutions are not required, but that visibility on energy consumption is, the two key questions that will define the complexity of the system are:

1) Are we collecting individual data from individual EV chargers, or just looking at them as a group?
    b. How frequently are we collecting the data? Each minute, hour, day, month, quarter?
2) How is the data conveyed to the interested person?
    a. In person inspection of an energy meter display?
    b. Charted and reported by email?
    c. Presented on a live cloud-based dashboard?

The next three sections cover several approaches along these lines.

Check-Metering

The most practical implementation of metering for a group of EV chargers will be to feed them from a dedicated distribution board, and install a basic check-meter with a visible kWh display.

At a glance, the person inspecting the energy meter will be able to identify the total amount of energy that has been supplied through the meter, which will have a direct correlation with cost. If this person is (for example) the site facilities manager, and is collecting this data point once a month or once a quarter, it will enable a trend to be drawn showing the change in energy use over time.

Figure 3

There are a few things that a solution of this nature won't do:

1) Identify when the EV chargers are being used
2) Identify how many chargers are being used simultaneously
3) Identify which specific EV chargers are being used
4) Automatically record and report the information

For cases where better data is required, the next step is to add a platform for collecting and collating this data.

Metering with Web Server to log and Report Data into Existing Systems

Taking the distribution board with the check-meter (Figure 3) as the starting point, it is possible to add an industrial web server and data logger to the board, and connect it to the check-meter.

The advantage of a solution of this kind is that it will log data from the energy meter on a periodic basis (eg. each minute, hour, or day), store this data locally, and make this data available via a typical web browser. Note that this device could be connected to the internet to enable automatic periodic emailing of data and reports, but that this is not essential.

It is perfectly feasible to connect devices of this nature to the existing building management system on a dedicated IP address. The facilities person from the previous example would be able to see in near real-time what the charging equipment is doing, and would be able to see by way of charts and downloadable excel data what the usage had been historically.

This example, even if we assume that only a single check-meter is installed, would let the facilities manager see:

1) When EV charging is typically happening
2) How much energy has been used, and precisely when it has been used
3) Roughly how many chargers are in use at any time (through looking at total loading on each phase at a given time, and knowing how powerful the EV chargers on those phases are)

One of the advantages of the web server approach is that a single web server can read multiple energy meters. So, if there is a desire later to drill down into exactly which EV charger is using the power, individual meters can be placed upstream of individual chargers.

It should be noted at this point that the data in this example is coming from an energy meter upstream of the EV charger, and not the EV charger itself. This is an example that will work for data reporting without any capability to communicate with the actual EV chargers, regardless of which manufacturer's EV chargers are being installed.

If the system being planned includes local load management as described in the 'Local Smart Load Management' section of this article, then usage data at the level of individual EV chargers is already going to be available in the local smart load management device, which will remove the need for separate energy measurement devices for this task. In this case, a separate web server may still be desired, but consideration should first be given to whether the data reporting required can be delivered by the smart load management device.

Cloud-Based Data Reporting

If a billing solution is being implemented either using an embedded network (see 'Direct Billing via an Embedded Network'), or using a cloud-based specialist service provider (see 'Transactional Cloud-based Billing'), data reporting and visibility can likely come from the same provider.

This said, if the billing at a transactional level is not required, or a separate and independent data reporting system is desired, cloud-based data reporting services from many vendors can be used.

To implement NHP InfoSyte on your project visit nhp.com.au/more/infosyte

SUMMARY

Load management	Billing	Data reporting
1 – no load management, suitable for small installations	1 – no special billing requirements, billing either not needed or captured elsewhere	1 – no special data reporting requirements
2 – electrical load management, suitable for use as a backup	2 – billing for access to charging equipment, not for electrical energy usage	2 – check metering, manually inspected
3 – local smart load management	*3 – embedded network using trade approved energy meters*	3 – Metering with web server to log and report data into existing systems
4 – cloud-based load management (consider using electrical as well)	*4 – cloud-based billing solution*	*4 – cloud-based data reporting*

Summary Notes

- Each vertical can be treated independently, but:
    - o Load Management 3 will typically give you Data Reporting 3
    - o Load Management 4 will typically give you Data Reporting 4
    - o Billing 3 will typically give you Data Reporting 3
    - o Billing 4 will typically give you Data Reporting 4
- Total system lifetime cost typically increases from 1 to 4 in each vertical
- Items (in italics) will require ongoing service contracts
- For data reporting, if option 2, 3, or 4 is required, how granular does the reporting needs to be?
    - o Individual data from individual EV chargers, or treating them as a group?
    - o Frequency of data collection - each minute, hour, day, month, quarter?

If you would like previous copies of Technical News, simply visit **the Media page* on NHP's website** and navigate to 'White Papers' or download the free NHP eCatalogues App on the iTunes or Google Play stores.

NHP Electrical Engineering Products
A.B.N. 84 004 304 812

NHPTNL80 2018

AUSTRALIA
nhp.com.au

SALES 1300 NHP NHP

sales@nhp.com.au

NEW ZEALAND
nhp-nz.com

SALES 0800 NHP NHP

sales@nhp-nz.com