4
Software & Integration

The EV Charging Infrastructure Designbook: Volume 4

Software & Integration



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The EV Charging Infrastructure Designbook:

Software & Integration

The previous installments of this series of guides about EV charging infrastructure focused on power, control and connectivity hardware respectively. For the concluding installment, attention will now be turned to the important software and system integration aspects of the whole design and implementation process. In particular, this will highlight the variety of services, initiatives and development/system management platforms that the different operations within the Avnet Group can offer to those involved in the creation, installation and running of such infrastructure.

There are now over 330,000 publicly accessible charging points[1] in operation across EU member states (based on data published by consultancy firm P3 Group). Though more are being installed every week, expectations are even higher. At least ten times this figure will be needed before the end of the decade, if demand is to be adequately addressed and the EU's pledge to reduce carbon emissions by 55%[2] in that time frame are to have any hope of actually being met. Charge station operators and municipalities, along with the OEMs that serve them, therefore need a high degree of engineering support – so that they can accelerate the roll-out process. There will also be a need for continuously updated data insights, so that infrastructure can always run with optimal efficiency.

According to Charge Up Europe[3], the greatest amount of installed charging infrastructure per capita is to be found in the Benelux and Nordic regions, followed by Germany, Italy and France. It is clear from ***Table 1***, that there is a large divergence between the charge point availability in some countries compared to others.

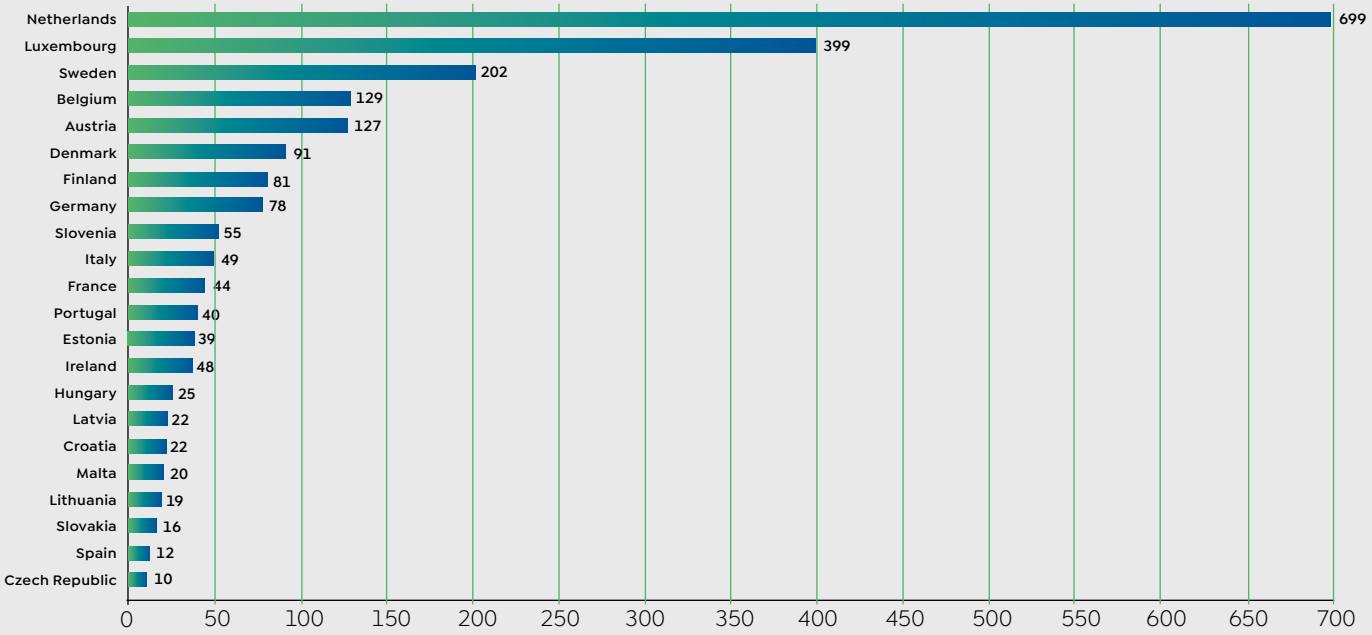


Table 1: *Installed public charging infrastructure in EU member states per 100,000 inhabitants [courtesy of Charge Up Europe/P3 Group]*

The unprecedented market potential of EV charging

If Europe is to reach a total of over 3 million charging points[4] for the public to be able to use by the end of this decade, then huge investment is going to be mandated. This will need to come from both the private sector and government funding.

A recent report compiled by industry analyst firm Grand View Research[5] expects the global charging infrastructure market to witness a compound annual growth rate (CAGR) of 30.6% between 2022 and 2030. This will mean that it has a £217 billion annual worth by the end of that period – presenting suppliers providing charge station operators with either hardware or software with highly profitable business opportunities.

Who's driving the implementation of charging infrastructure?

Each looking to gain market share at an early stage, numerous dedicated charge station operators have emerged. However, it should be noted that they are only part of a much bigger picture. As well as these companies, established petrol suppliers (such as Shell and BP) are placing an increasing number of charging points at the outlet locations – signifying that they are responding to the shift in their customers' requirements envisaged over the coming years. This is motivated by many expert sources now predicting a much more rapid switch over in relation to new vehicle sales, with EVs almost certain to surpass internal combustion engine (ICE) vehicles by the summer of 2025[6].

There are lucrative openings for supermarkets and other retailers to provide charging points too, as well as hotel, restaurant and cinema chains. Having charging points in their car parking amenities will be of obvious benefit – helping them to secure greater brand loyalty and boost customer footfall. Among the companies already making major financial outlay here are Tesco (in partnership with Volkswagen), Holiday Inn and IKEA. There is the option for such retail and hospitality locations to make their pricing more appealing than for roadside charge stations, in order to encourage greater patronage. Also special offers could be provided, such as if the EV driver spent over a certain amount in the store that day, they would get a certain amount of charging time for free.

Charge station essentials

Before describing the different system integration elements that EV charging infrastructure will need to encompass, it is important to understand things from a user perspective. Here is a brief overview of all the key facets that EV drivers will want from a charge station:

- Accessibility – This must be both in terms of station positioning and the number of available charge points at each site.
- Seamless user experience – With it being paramount that every stage of the charging process and each individual interaction involved will all run smoothly. If any frustrations arise, then the driver may look to use another charge station operator's facilities in the future.
- Expediency – The whole charging procedure needs to be completed within the shortest possible length of time, so that the EV driver can get back out on the road again.
- Secure financial transactions – The EV driver must have absolute confidence that their banking details are not vulnerable to the threat posed by hackers.
- Assured charging capabilities – If an EV driver is unable to charge their vehicle sufficiently due to supply issues, then this could have serious implications for them. It will almost certainly mean that (whenever possible) the charge station operator would not be used, and most likely result in the driver letting other people know about the poor service they had received.

From an operational standpoint it will be equally important that the following points can likewise be dealt with. These are:

- Attaining maximum revenues.
- Keeping the associated operational expenses (such as equipment maintenance) down, so as to raise profitability levels.
- Gaining repeat business through the quality of service provided.
- Responding to changing situations, both in respect of customer requirements and the electricity supply coming from the grid.
- Preventing downtime.
- Protecting brand reputation.

Finding charging facilities

To attend to charging requirements across the largest possible area, EV charging infrastructure needs to be distributed in such a way that supply can be matched with user demand. Single charging points will be more densely deployed in cities or large towns than in rural areas. Charge stations will be periodically situated at different points on highways.

EV drivers will need to identify where charging points can be found, and if they are available for use. This can be done through a smartphone app. The app can also plan out the best route for the EV to take, navigating how it will traverse the urban environment from its current position. An app could also inform drivers of the distance that must be travelled along a highway before the next charge station is reached. This will mean that charging stops can be planned into journeys, and the 'range anxiety' issues that EV drivers often have can be allayed.

User authentication

For any public use charging point – whether it is an unmanned unit on a residential street or one of the outlets found at a large charge station at the side of a highway – there is the potential for unauthorized users to attempt to draw electricity to charge their vehicle without paying for it. Municipalities and charge station operatives must therefore be vigilant, and ensure that effective user authentication mechanisms are put in place.

Before any transaction begins, verifying that the customer is who they claim to be is clearly of critical importance. At the foundation of the authentication process will be transport layer security (TLS), where there is an exchange of cryptographic keys. The advent of the ISO 15118-20 protocol, which replaces the precious ISO 15118-2, will not only make the authentication process more robust – it will also mean that multiple contracts can be held by the EV. The upshot of this is that an EV driver can have subscriptions with several different operators (something that the old version was not capable of supporting, which caused serious limitations). It also allows the holding of separate contracts relating to the driver being able to charge their EV at their workplace, at their gym, etc.

There are a variety of the different authentication methods that may be employed, permitting access to be provided or restricted accordingly. The most commonplace mechanisms will be based on use of:

- A smartcard reader to check the customer's credit card details.
- An RFID reader that takes data from a transponder (usually attached to the customer's key ring).
- Interfacing with a mobile app (via NFC).
- A vehicle identifier (directly incorporated into the EV itself).

Potentially, each of these has its own particular strengths and weaknesses that designers need to be aware of. For example, if the EV is stolen, then the built-in identifier will allow the thief to recharge the vehicle (unless this is deactivated as soon as the theft is reported). In most cases, a combination of different authentication options will need to be incorporated, with one then being used to back up the other.

Through the RFID, NFC and smart technology that Avnet Group offers – from vendors like STMicroelectronics and NXP – alongside supporting software, the authentication stage can be kept straightforward and convenient, but still be fully effective. The result is automatic customer recognition and 'zero touch' charging.

Interaction during the charge session

Generally a smartphone app will be employed to initiate the charging process. It can confirm the tariff and inform the driver if a time limit is reached (which will lead to the tariff being increased). In addition, the app will make sure that the charge gun is attached correctly (and there are no safety concerns). Leveraging advanced metrology, the energy flow between the charging point and the EV can be monitored, and the driver alerted of any issues through the app. Also safety mechanisms can be put in place to protect against overheating, etc. Anti-tamper detection can be featured too, to prevent illegal activity.

For charge station customers not using an app, the process can be initiated via capacitive sensors in the gun. Once valid attachment has been confirmed, charging can begin and the EV driver may then refer to the graphic user interface (GUI) integrated into the charging equipment to see details about the session.

For a wallbox located at a house or in a residential building, the charging process is similar, but there are still several differences that should be noted. Initiating charging will be much the same – with sensors checking that the charge gun is correctly attached, and the charging tariff from the utility at that time being confirmed. Operational management is necessary here to make sure that charging does not interfere with other household activities. If only a certain amount of electricity can be supplied then heating and lighting, for instance, will be prioritized.

Payment systems

To provide accurate billing to the customer, the payment system will need to have detailed data relating to the charging session. This will need to cover the period over which the session ran, the total charge delivered in that time, etc. It must also take into account any tariff changes that took place over the charging session. This could be due to the session going from the utility company's off-peak rate to its peak rate, or the charge station operator applying an additional surcharge if the session goes for longer than an hour (as a charging point that could be used by another customer is not being made available).

There could also be information relating to different customer types that needs to be considered – for example, freight carriers may have negotiated a discounted rate with the operator for volume business (allowing their trucks to be charged at a lower cost as a result). Also, in certain countries (such as Germany), the disabled will be permitted to charge their e-mobility vehicles for free.

The vast majority of EV drivers so far have decided to opt for having some form of subscription with charge operators[7]. They are thereby able (after completing user authentication) to get the charge session billed to their account at the end of the month. Payment is then simply taken automatically. To encourage people to sign-up as a subscriber, loyalty programs can be put in place where preferential rates or other perks might be offered. By having such programs, operators can attempt to gain a greater share of the customer base, with EV drivers more likely to seek out charge stations where their subscription is valid.

For those who would prefer the flexibility of not having a subscription, the ability to pay via a smartphone (using Apple Pay, Cash App, etc.) or credit card will need to be included. If on-site interactions of this kind are going to be carried out, then having superior payment security will be something that the charge station operator simply cannot afford to overlook. One of the other advantages that ISO 15118-20 has over the older ISO 15118-2 protocol is that longer cryptographic keys can be utilized, leading to stronger security.

Until now, charge station operators have relied on their own unique payment system apps. It is feasible though that consumer pressure will lead to a consolidation here.

Payment mechanisms may become unified, meaning that charge station operators need to offer interoperability with those of the rivals.

GUI construction

As already described, while at a charge station or public charging point, the EV driver will need access to a multitude of different items of data. Even before they look to start a charging session, they will want to know the power available at that time (if there is limited charging due to high grid demands), the tariff, plus the period for which that tariff will remain valid. Once charging has been initiated, they may want to check what the current status of the session is (the charging rate, the battery's state of charge, upcoming tariff changes, etc.). To get hold of this information, they will access a GUI.

Using NFC, a smartphone handset can serve as a conduit for the charging equipment's GUI. Consequently, the EV driver may look at an app and have the freedom to move around while still checking what is happening. Alternatively, they can use the display built into the charging equipment (though they have to stay nearby in this case).

An extra function that the GUI could provide while charging is taking place is third party advertising. As they are effectively a 'captive audience', drivers could be shown adverts while they are waiting for their EVs' batteries to be replenished. This could serve as another revenue stream for charge station operators.

In order to deliver maximum convenience to the customer, the GUI must be as intuitive as possible. This will mean that the authentication, charge initialization and subsequent payment process all remain straightforward and the prospect of customer annoyance can be avoided. So as not to cause confusion, it will be important that there is consistency between the GUI seen on the smartphone and one that is rendered on the charging equipment's display.

GUI construction is an artform that most electronics engineers have little real experience of. Making it simple for users to work with, and having sufficient visual impact on both a relatively large display and smaller handset-enabled version can be difficult. This is why getting advice off professionals with all the applicable knowledge is prudent.

Anomaly detection

The ability to uncover any anomalies arising will be vital if a charge station operation is to achieve maximum profitability. Data relating to numerous different parameters will need to be captured and then supplied to the backend system. Here, using artificial intelligence (AI) algorithms, any unusual patterns or behaviors may be pinpointed. These could indicate that there is some form of malfunction at a charging point in the charge station, or signify that an attempt to steal charge is underway and action needs to be taken.

V2G – a new paradigm

Until now electricity distribution networks have predominantly relied on power stations burning fossil fuels as their source of supply. This is all in the process of changing though, as the proportion of electricity coming from renewable sites (wind, solar, etc.) increases. Due to the irregular nature of these forms of energy generation (which are constantly changing throughout the day, as well as seasonally), counterbalancing mechanisms are needed to maintain grid stability – with electricity being stored for utilization when renewable output is at a low ebb. As EVs will generally have relatively low utilization rates for much of the time (just travelling short distances), their batteries could be pivotal in enabling the electricity storage needed to support the grid – hence mitigating the risk of power outages.

In addition to helping augment charge station authentication and payment security, a further benefit of the ISO 15118-20 protocol is going to be its ability to support bi-directional charging. The vehicle-to-grid (V2G) technology that results from this opens up the possibility for EV batteries to act as a source of electrical power, not just a sink.

When applied in a residential context, this signifies an exciting new advance. It will allow EV owners to transfer power back to the electrical distribution network (in return for financial reimbursement) – compensating for variations in renewable electricity generation (where the output depends on how much sunshine there is or how hard the wind is blowing).

What follows is a simple scenario. This illustrates how communication undertaken by the wallbox would mean that the needs of both the grid and connected EVs may be attended to – with both being met by correctly scheduling which of these should be prioritized at different points in time.

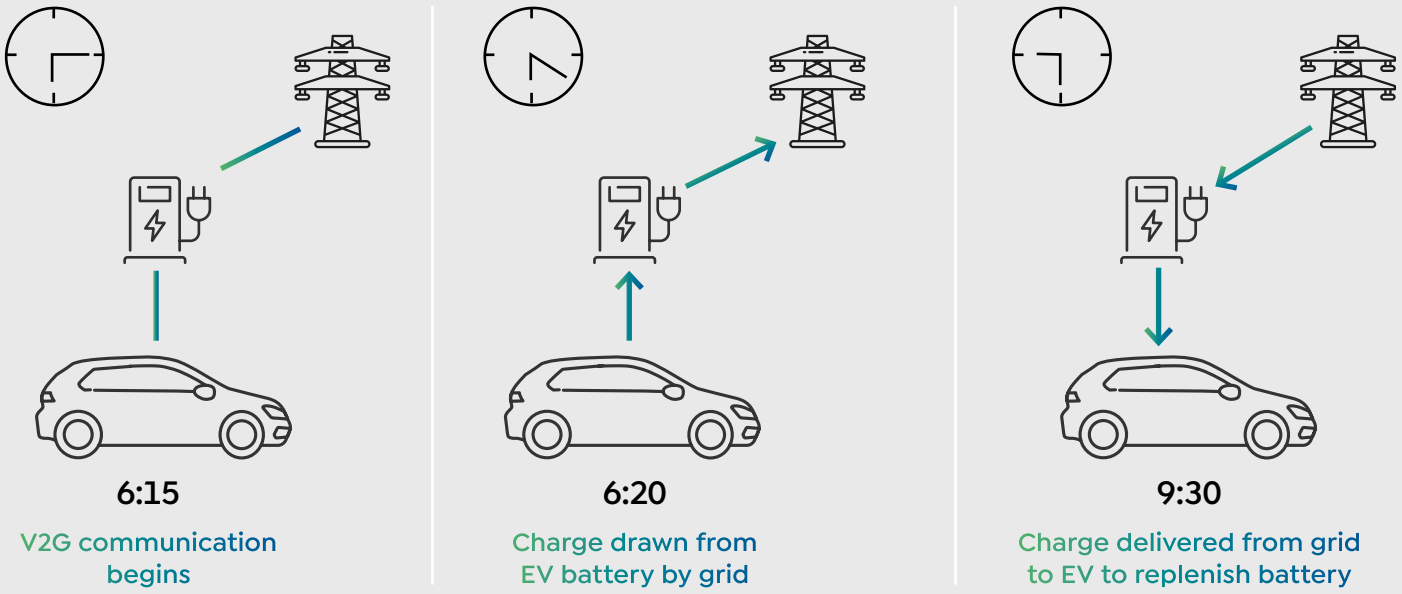


Figure 1: *Using EVs to maintain grid stability through bi-directional charging*

An EV driver returns home from work at 6:15pm in the evening. They connect their vehicle to the wallbox installed there. Through V2G, the wallbox then interfaces with the grid. From this, it can ascertain what the current grid consumption demands are. If it is apparent that demand is particularly high at that time, then the wallbox can make the battery of its connected EV available to the grid, and delay charging operations until later. After the financial terms have been confirmed, the remaining charge in the EV battery (and numerous other connected EV batteries) can be accessed through inverter hardware. It may thus be used to supplement the grid's electricity delivery capacity, in return for monetary reimbursement. After the demand levels have subsided (say at 9:30pm), the wallbox will be informed. Recharging of the EV can then begin, with there still being ample time for its battery to be replenished before it is needed the following morning.

By having the option to use their EV's battery as a revenue generator, owners will be able offset some of the initial cost associated with buying such vehicles. It must be noted though that doing such activities on a regular basis will shorten the lifespan of the battery (so this should be factored in). Nevertheless, the income that can be derived will undoubtedly make this worthwhile.

Though this is an appealing prospect for individual EV owners, it becomes even more interesting when it can be applied to a fleet of EVs. Companies with large numbers of these vehicles will be able to pool battery reserves together and support the grid on a much greater scale. This will allow them to take a considerable amount off their day-to-day operational expenses.

Managing localized energy storage and microgeneration activities

To maintain supply continuity at all times, charge station operators will need to install large battery banks. These will supplement the electricity coming from the grid at times when EV customer demands are particularly high and the grid simply cannot keep up. Using such energy storage reserves, operators will have a buffer that they can draw from whenever necessary. The batteries can be charged up when the grid is not under particularly heavy strain, meaning lower a time of use rate (TOU) too. They can then be brought on-line during the morning and evening rush hours, before being recharged again ready for the next peak in customer activity.

Access to local renewable energy generation (such as solar panels on the charge station roof) will also be advantageous, presenting another means for alleviating the demands being placed on the grid. As well as being able to interface with the grid, the charge station operation will need to manage its on-site energy generation and storage capabilities, in order for it to effectively deal with customer demand and avoid the risk of supply disruptions. These functions will call for a multi-faceted AI-enabled system.

System updates

Charging infrastructure implementations – whether they are in the domestic, enterprise or commercial supplier environment – will need to keep on evolving after their original deployment. The use of firmware-over-the-air (FOTA) updates will therefore be vital. This will enable new features and functionality that will prove compelling to customers to thereby be added in a cost-effective and time-efficient way. Having a system integration arrangement that facilities FOTA updates is thus going to be advisable.

Maximizing the effectiveness of backend operations

Fundamental to the success of a charge station operator's business will be how well its backend has been implemented. Based on the various sections that have already been described, it will be necessary for this to cover:

- Load management – So that the demand at a charge station at any given time can be balanced accordingly, with back-up energy storage or microgeneration assets being brought on-line should the grid be unable to cope during that period.
- Implementing pricing changes – Thereby allowing any TOU fluctuations due to grid demand to be attended to, as well as enabling promotional campaigns and other tariff-related actions to be undertaken.
- Tariff handling – So that customers can be encouraged to charge their vehicles at times when demands on the grid are less intense (thus lowering strain being placed upon it).
- The managing of on-site renewable assets – This will entail having the ability to predict what demand will be during different phases of the days. By combining this consumer demand data with data coming from weather stations in the vicinity, judgments can be made about what percentage of the charge station's demand can be met by renewably generated electricity, and how much will have to be drawn from the grid.
- Other grid interactions – In order that microgeneration contract exchanges (to help with grid stability) can be dealt with, etc.
- Management of business-to-business (B2B) service agreements with freight companies, public transportation providers and suchlike.
- Preventative maintenance – So places where malfunctions might occur can be uncovered early on (and downtime averted).
- Detailed exploration – Through the continued capture of data regarding customer behavior (while still respecting GDPR legislation) and geographic usage heat maps, strategic decisions may be made. In many cases, the analysis involved will be done using AI. The outcome of this will be that resource availability can be better matched with customer requirements and future consumption projections prepared for.

Having edge-located intelligence will be at the heart of delivering all these functions. It will enable more rapid responsiveness to changing circumstances. In addition, it will act as material that fuels data analysis. Providing the backend system with large quantities of data on an ongoing basis will make it possible to formulate better operational and commercial strategies – resulting in the business being healthier and combating sources of potential weakness.

The need for effective cloud-based system management

By having a sophisticated backend system installed, in-depth analysis can be undertaken on all aspects of a company's charge station operation. A better understanding of each charge station location may be derived and adjustments made that will help to accentuate their revenue generating capabilities. Also, by scrutinizing customer usage patterns, new charging station sites can be built at places where there is greatest need.

Already being employed by many leading charge station operators, Avnet IoTConnect represents an invaluable tool for this sector. It provides them with a comprehensive end-to-end solution that is highly adept at supporting the orchestration of complex IoT network distributions, resulting in a dramatic streamlining of the management effort and significant time savings.

Using this Azure-certified enterprise-ready platform, which is already field proven in the EV charging infrastructure sector, charge station operators are able to develop, implement and subsequently manage large-scale charging operations. Automation of many of the key functions minimizes the human resources that need to be allocated – with load balancing, pricing alterations, energy storage/microgeneration control, plus interactions with the grid all being done via state-of-the-art AI algorithms.

Use of an Avnet IoTConnect dashboard for managing EV charging infrastructure

Telemetry capabilities mean that real-time monitoring of all the parameters associated with each of the charging points can be conducted, as well as there being provision for remote diagnostics plus troubleshooting. Rules can be defined that will automatically trigger specific actions if certain conditions occur.

The inherent scalability of this platform permits new charging points or charging station facilities to be added to the system once their deployment has been completed. Creation of smartphone apps to accompany the backend implementation, offering captivating user experiences, is also facilitated.

Design logistics

EV charging infrastructure is becoming an extremely competitive sector. So as not to miss out on windows of opportunity, charge station operators and wallbox manufacturers both need to be able to complete development projects in the shortest possible time period. Rather than being forced to start projects from scratch, a modular approach will mean that time and engineering are better utilized, unwanted errors are not made, and time to market pressures are eased. The technical support and guidance that the Power of Three team can offer will also make a real difference.

Complementing the hardware technology supplied by Avnet Abacus and EBV Elektronik, the design team at Avnet Embedded is helping to redefine EV charging infrastructure development projects. Its software expertise is able to support charging equipment OEMs with regard to every element of the software development and integration process. This covers customer authentication, payment systems, GUI construction, operating system customization, backend implementation, reporting, consumption level predicting, etc.

Furthermore, the Avnet Design Hub will markedly accelerate project progression. Users can access charging infrastructure related reference designs (covering the power, GUI, payment and security elements). These will give them a head start, while still having ample scope for adding differentiation that will set their products apart from those of the competition.

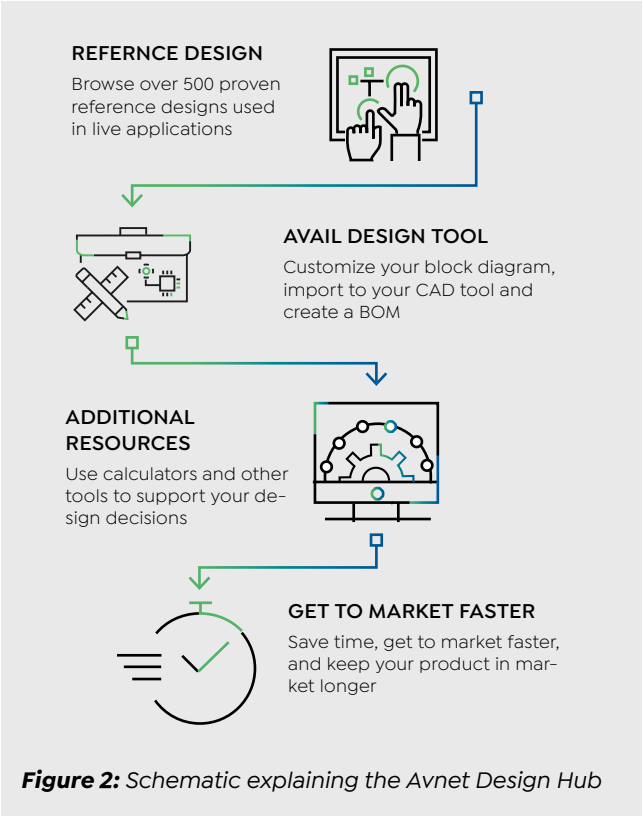


Figure 2: *Schematic explaining the Avnet Design Hub*

Conclusions

So this brings the final installment of this EV charging infrastructure design guide to an end.

In these four documents all of the principal constituent areas of which charging infrastructure is comprised has been gone through in turn. For each of them, the specific engineering and logistical challenges that are posed have been explained, then ways to overcome them outlined.

By referring to the design guides, the OEMs and systems integrators involved in this sector will be able to get useful insights into how they might enhance their infrastructure development projects, discover ways in which systems can be better managed once they have been deployed. To engage with the Power of Three team on your next EV charging infrastructure project click here.

Questions?

If you have any questions about the topics discussed in this guide, or you're ready to take the next step with your design, **reach out to our EV charging experts** - they're some of the best in the industry.

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