ELECTRIC VEHICLE CHARGING EQUIPMENT AND SITE TECHNICAL CHALLENGES.

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Abstract As the charging of Electric Vehicles (EV) increases, so does the demand for skilled engineers required to specify, design and commission charging sites. When transferring from traditional oil and gas or commercial industries, some technical equipment, design and requirements are specific to EV charging site designs.

This paper has been written for engineers entering the EV charging discipline as a gap bridging training offering. It discusses the most significant topics relevant to EV charging installations prevalent to this low margin, high quantity and multiple country industry.

Index Terms — Electric vehicle charging, EV site design, Electric vehicle chargers, electrical supply equipment, electrical design.

I. INTRODUCTION

Whilst assumed simple in design and application, the heart of EV charging can be complex, especially when working across multiple geographies, standards, products and designers.

Engineers entering the EV charging environment may originate from other industries such as oil and gas, commercial or the energy sector. This document outlines some key technical elements that the engineering discipline has been required to address when working in this growing industry.

The purpose of this paper is for an engineer to quickly close any new industry knowledge gaps.

The paper focusses on the engineering aspects and not the entire industry related to EV charging.

II. CHALLENGES

EV charging sites present unique challenges. These can be summarized as “The Pertinent P’s”.

- Place
- Power
- People
- Products
- Procedures
- Payment

Understanding these will assist engineers working in this industry.

III. PLACE: SITE DESIGN

When identifying and selecting a suitable EV charging site the engineer needs to consider a few key factors:

- Location - basement, enclosed car park, open area, green or brownfields.
- Ownership of power connection, electrical equipment, EV charging equipment, convenience etc.
- Space for target number of charging bays, number of accessible bays, travel distance for the customer and distances between major equipment (substations, transformer, EVC power banks, EVCs).
- Expected charging speed.
- Expected power requirements.
- Demand and utilisation assumptions for economic modelling, diversity factor and load management.
- Electrical Utility power availability and schedule to upgrade.
- Location of hazardous areas, flammable materials, EV fire and fire escalation risks, proximity to buildings adjacent to the target site.
- Review requirement for remedial works that significantly affect the overall scope – e.g., resurfacing, demolition works, contaminated soil remediation, drainage, fencing or landscaping requirements.
- Likelihood of underground structures (tanks, pipes) that may affect earthing design.
- Convenience offers and/or drivers lounge, size, toilet and/or shower facilities.
- Inclusion of a canopy including size and type.
- Requirement for ancillaries such as CCTV, additional lighting, customer Wi-Fi.
- Plans or allowances for future expansion, e.g., addition of more chargers, replacement of chargers and cabling with higher power models.
- Historical use of the site (that may indicate below ground hazards or contamination).
- Proximity to hazards (e.g., flammable materials).
- Vehicular movement, traffic flow, pedestrian risks.
- Risks to planning permission being granted (e.g., proximity to residential areas, installed equipment or building heights, lighting design).
- Environmental conditions including flooding risk, seismic zone, altitude, maximum 24 hours average and peak ambient temperatures, solar irradiance
- Potential noise from equipment (transformer hum, power bank fans, EMC effects, …)
- Site design: parking layout, pull through charging options (islands to allow side on charging - e.g., trucks), overnight charging, gantry located chargers (e.g., reverse parked trucks)

Engineering should be involved in site visits, inspection, review of site appraisals and site feasibility reports and participate in final site decisions.

IV. POWER:

A. *Utility Connection Requirements*

EV chargers consume significant amount of electrical power. In most cases, the Land or Asset team will find a suitable site that requires a power upgrade.

Countries have many and varied Distribution Network Operators (DNO). Understanding these DNO's specific requirements is challenging for engineering teams, designers and the manufacturer. The large variation in technical requirements largely leads to the non-standardisation of electrical supply equipment.

Electrical engineers need to calculate the total power load, and, in some cases, provide the harmonic profiles of the connected equipment.

DNO technical requirements could vary in many aspects. For LV grid connections applications, some of the main variation points include:

- Heavy-duty cut-outs.
- Current transformer specifications for Energy Supply Meter.
- Specification of Energy Supply Meters for billing purposes.
- Earthing arrangements.
- Smart grid monitoring devices.
- Insulation class of LV switchgear (i.e., class I or class II).

For HV grid connections applications, some of the main variation points include:

- Specifications of HV switchgear.
- HV switchgear protection devices (e.g., TLF or OC/EF relays).
- Specification of Energy Meter for billing purposes.
- Location of Energy Meter within the substation.
- Grid connection voltages (i.e., could vary from 10kV to 25kV for ring connection applications)
- Earthing arrangements.
- Smart grid monitoring devices.
- Location and boundaries of DNO interface asset (e.g. HV switchgear)
- Enclosure type of prefabricated substations (i.e., concrete, GRP or metallic).

V. PEOPLE:

A. *EPC Designers and Construction*

Most charge point operators do not have the capacity or capability to engineer, procure and construct sites. As such EPCs are sourced and contracted to perform this activity.

Within the O&G industry, EPCs are well versed with hazards and risks involved and generally charge higher rates.

When translating similar risk mitigation, standards compliance, engineering designs and project management to commercial type EPCs, capacity and capability challenges are experienced. Greater quality assurance and control measures, project management support, documentation control, resourcing, roles and responsibilities, schedule and performance management are required.

Construction management in this nascent industry requires additional EPC and client oversight. Local construction regulations (e.g., CDM) become the minimum requirements.

Identifying global EPCs and resourcing contractors in a competitive industry is proving increasingly challenging.

Engineers need to prepare for a greater hands-on approach.

VI. PRODUCT:

A. *EV Chargers*

1) *Distributed or Integrated Chargers*

An integrated EV charger converts LV AC into DC at the charge location. It includes a human machine interface (HMI) and charging cable and is stand alone. See Figure 1.

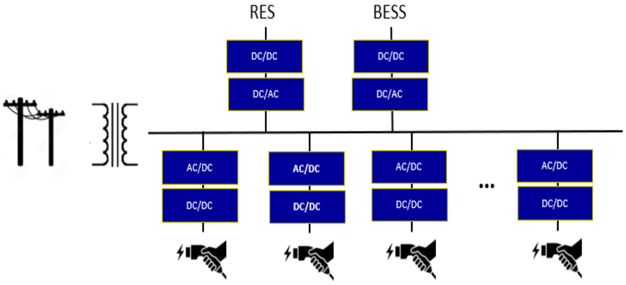

Figure 1. Integrated charger

A distributed charging system includes a separate power bank where power is shared from a common AC or DC bus system to several AC/DC/DC/DC or DC/DC power modules. This power source is then distributed to a number of charge points, satellites, charging piles or charging stools.

The Charge point houses the connector cable and possibly a HMI and or payment terminal. For a DC bus system, the charge point footprint is usually reduced as the power conversion is performed in the power bank housing the power modules (shown as power module unit below the AC bus in Figure 2).

Power can be shared across various charge points as their demand fluctuates, offering a better overall power utilisation that individual chargers. Load management becomes inherent in this design.

The AC or DC bus system can be used to include battery energy storage systems, solar or other forms of power. See figures 2 and 3.

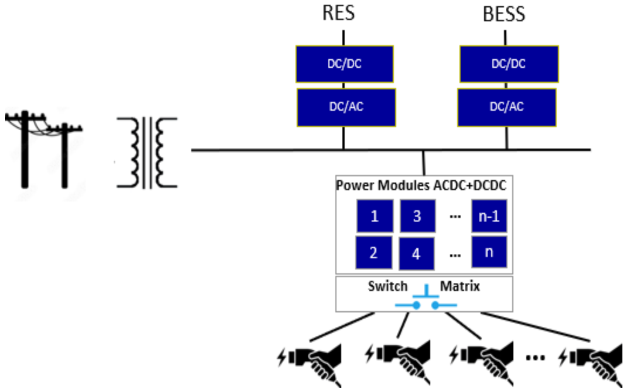

Figure 2 Distributed AC Bus charging system

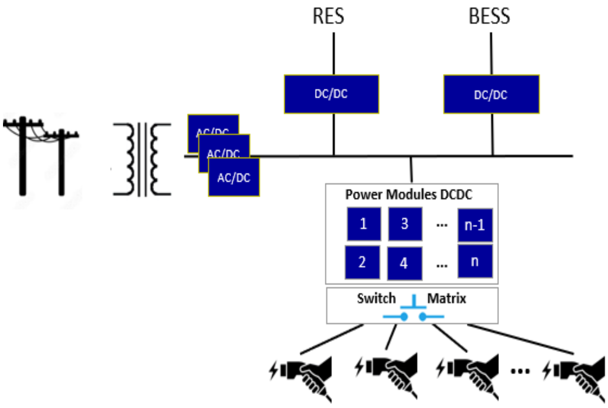

Figure 3 Distributed DC Bus

See Appendix A for a summary of the considered differences between integrated and distributed chargers.

2) Power Module Design

A high-powered DC EVC converts AC into DC using a series of power modules. These vary in power rating and currently EVC OEMs manufacture these units from 20 to 75kW. Using a combination of these together offers optionality in how two simultaneous users can be powered. Power sharing splits of 0/100%, 40/60% or 50/50% are common.

Each power module employs semiconductors and bespoke designed circuitry to manage the AC/DC conversion.

Semiconductors used in power include IGBTs and MOSFETs. Most manufacturers employ silicon as the base material. Higher efficiency silicon carbide (SiC) types are becoming popular. Gallium Nitride (GaN) is a future material with an improved efficiency. High frequency switching generates ohmic resistance leading to heat which needs to be dissipated. This heat accounts for the majority of the losses within an EVC and needs to be factored into site design and commercial models.

A high granularity in the prudent use of power modules at various utilisation levels can manage the efficiency and losses within an EVC. This single factor in the design of an EVC can separate industry OEMs apart. [[1]

3) Efficiency Calculations

DC EVC's convert AC to DC using semiconductors (IGBT, SiC, GaN). These generate heat due to the switching frequency resulting in losses. Transformer, cable and switchgear losses account for about 3 % losses, but EVC losses account for about 6%+ and are deemed to contribute the greatest losses across the power circuit on the EVC site.

EVC OEMs report efficiency of their EVC's at typically two values - 20-80% and 80-100%. This is because EVs charge rapidly from a low state of charge to about 80% and typically that the same time to charge the remaining 20%. Charging is not linear (see Figure 4)

EVs have varied charging requirements as shown in figure 4 below. Note the high initial requirement and the rapid tail off. This is significant and contributes to site load management, charger profiles, modelling and marketing opportunities.

Standby losses are important parameters that assist in determining energy losses based on the utilization percentage. Considering a 4% site utilization (charging time over a year), the standby losses will be observed for 96% of the year – i.e., most of the time, power will be used to retain the standby loads rather than charge the EVs. Any parasitic loads (cooling, heating, lights, site consumers) should be carefully considered when modelling sites for return on investment. Prudent engineering design is required to reduce these base loads.

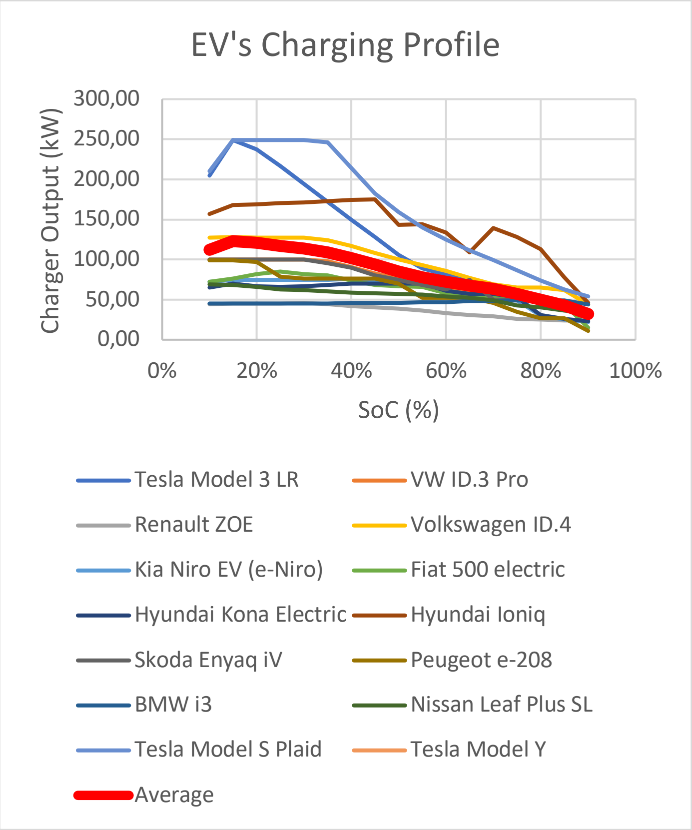

Figure 4 Typical EV charging profiles

An EVC efficiency evaluation tool was developed to determine varying efficiencies at various utilisation profiles to support the commercial model.

Three main key inputs that are required:

- the efficiency of the charger at different output power levels.
- the charging profiles of the most popular EV's.
- the size of their associated batteries in kWh.

The efficiency performance graph of each EVC is required to accurately determine the losses during each charging session. Almost all EVC's efficiencies drop at lower power output requirement levels (higher state of charge - SOC). Thus, towards the end of most charging sessions (between 60-90% SOC) the efficiencies of the chargers drop as less power is being delivered to the EV's battery. The time taken to charge from 20% to 80% is similar to charge from 80% to 100% and few EV drivers using on-the-go chargers charge to 100%.

The charging profile of the EV and the size of the battery are both required to determine the amount of energy required by the EVC at different SOC's. For example, the maximum amount of power a Tesla Model S Plaid can draw from a charger at 20% SoC is 249kW, whereas at 75% that will be 87kW (assuming here the charger can output more than the required 249kW). This is important, as many EV drivers complain that the EVC cannot provide the quoted power to their EV, when the EV battery management system does not require that rated power. Understanding and correctly applying efficiencies in designing and modelling are vital to ensure accurate and optimal outcomes.

VII. PROCEDURES:

A. Electrical Design - Earthing protection against electric shock

Earthing (grounding in the USA) provides a safe path for current to flow in the event of a fault.

EV charging installations should not use the protective measures offered by 1) using obstacles or placing energised systems out of reach or 2) earth-free local equipotential bonding.

Different types of earthing systems exist across the globe, regions and applications.

TT earthing is commonly used for EV charging installations. One part of the system is directly connected to earth independent of the source earth electrodes.

TN-C (or TN-C-S) – also known as protective multiple earthing (PME) are common across predominantly the UK. Here the neutral and protective functions are combined (C), separate (S) or combined in part of the system (C-S).

For TN-C systems – the final circuit supplying the EVC shall not include a combined neutral and protective conductor (PEN)

For TN-S systems, these are treated as TN-C-S systems unless it can be guaranteed by the utility supplier that the TN-S system will remain a TN-S system all the way back to the supply transformer and not be converted to a TN-C-S system later. This is usually challenging to guarantee if the transformer is not part of a private network.

For TN-C-S systems the requirements are somewhat more onerous. A PME earthing system used as the protective conductor for a charge point used outdoors requires one of the following methods to be adopted:

1. The charge point is part of a three-phase installation supplying EVCs and other loads, and in the event of an open circuit fault in the PEN conductor of the LV network supplying the installation, the maximum voltage between the main earth terminal of the installation and earth does not exceed 70 V rms.
2. A protective conductor of suitable diameter connects the main earth terminal of the installation to an installation earth electrode. The resistance of this earth electrode is such that in the event of an open-circuit fault in the PEN conductor of the LV network terminal, the maximum voltage to earth does not exceed 70 V rms.
3. A protection device (or similar device that is not less safe) which electrically disconnects the EV from the live supply operates within 5 seconds in the event of a voltage exceeding 70 V rms to earth, due to an open-circuit fault in the PEN conductor in the LV network.

Refer to local wiring regulations. [2]

If considering converting the system to a TT system, an assessment of buried metal work, earth electrodes and uninsulated conductors will be required. Simultaneous contact between two earthing systems, overlapping of different earthing zones are to be considered.

When high voltage equipment is required, consider the earth/ground potential rise (EPR) or (GPR). This occurs when a large current (e.g., fault current) flows to earth through an earth grid impedance. The potential is the highest at the point where current enters the ground and declines with distance from the source. The EPR around a substation may cause the voltage over distance (potential gradient) to be dangerously high between a person's two feet or between the ground on which the person is standing and a metal object. Any conducting object connected to the substation earth ground, such as re-fuelling equipment, rails, fences, or metallic piping, may also be energized at the ground potential of the substation. This transferred potential is a hazard to people and equipment outside the substation area.

Soil resistivity, underground metal objects and the distance between high and low voltage substations affect EPR. This may result in the HV and LV substations being up to 8 m apart. Many forecourts do not have this available space, resulting in the site being unsuitable for EV charging. Specialist software exists to calculate EPR and provides a complete earthing study (e.g., Current Distribution, Electromagnetic fields, Grounding and Soil Structure Analysis – CDEGS)

B. Electrical Design - Electric shock protection [2]

Electric shock protection is achieved by means of an overcurrent protective device meeting a disconnection time of 5 seconds for a TN system and 1 second for a TT system. If these disconnection times cannot be met, then a residual current device (RCD) is required.

Fire protection against insulation faults in areas with risks of fire due to the nature of processed or stored materials require an RCD with a rating not exceeding 300mA for TT and TN systems.

There are many different RCD types available, each being suitable for different types of equipment.

Circuit-breakers are manufactured according to their time/current characteristics and are available in types B, C and D. Care should be exercised not to confuse an RCBO with a B Type time-current curve for a Type B RCD.

Selectivity (previously the term "discrimination" was used) needs to be achieved when installing multiple RCDs in series. Time-delayed or S type devices installed upstream achieve this.

1) Application of RCDs

It is important to select the correct Type of RCD for the characteristics of the equipment to be used. **Erreur ! Source du renvoi introuvable.**, [3]

Type AC RCDs (General Type[4]), which are most commonly installed in dwellings, are designed to be used for alternating sinusoidal wave residual current only to protect equipment, which is resistive, capacitive or inductive and without any electronic components.

Type A RCDs are used for alternating sinusoidal residual current and for residual pulsating direct current up to 6 mA.

Type F RCDs [5] are used for frequency-controlled appliances and equipment.

Type B RCDs [5] are used for single and three-phase equipment and are also suitable for Type AC, Type A and Type F applications.

Type A EV RCDs are used for single and three-phase, DC pulsating and DC smooth (≥ 6mA) equipment. These are suitable for EVC installations but are restricted to 80 A.

Where electric vehicle charging equipment is likely to create a residual DC fault current, engineers need to consider the correct type of RCD within the charging equipment circuit. Type AC RCDs cannot identify ((become 'blind' to) the residual DC component and if the AC input side is galvanically isolated from the DC output which provides electrical separation, faults on the DC output side, connected to the vehicle, would not be detected by an RCD on the input side of the circuit, but by a sensor in the DC supply.

Residual/leakage current components					**Transient Resistance**
RCCB Type	**AC 50Hz** ∿	**AC 50Hz Pulse** ∿	**Smooth DC** ⎓	**AC>50hZ <kHz** ∿	**3kA/20µS Current Wave**
AC	✓	✗	✗	✗	✗
A	✓	✓	*<6mA$^{(1)}$	✗	✗
AKV	✓	✓	*<6mA$^{(1)}$	✗	✓
F	✓	✓	*<10mA$^{(1)}$	✓	✓
B	✓	✓	✓$^{(1)}$	✓	✓
EV	✓	✓	>6mA$^{(2)}$	✓	✓

1. Type B RCCBs detect DC residual current and trip if the smooth DC current exceeds the trip threshold.

* Type A, AKV and F will function safely with smooth DC residual currents present up to the levels indicated, but they do not detect smooth DC. Do not install upstream of Type B RCCBs.

2. Type EV RCCBs trip if the smooth DC current >6mA i.e. they must only be used for protecting a single charger.

Table 1 RCD types [6]

C. *Electrical Design – Diversity*

Some country regulations require that a site diversity of 100% be used when allocating the number of EVCs to the incoming supply. [2]

Site utilisation is generally nowhere near 100% (it can be single figures initially) and EVC demand adopts the curves shown in figure 4 – i.e., not a constant full power demand.

Load management allows for the effective power control of connected EVCs by restricting the available power to each EVC.

Factors to consider when determining site diversity may include:

- Average EV battery charging power requirement.
- Use cases (On-the-go, Destination, Fleet, eTruck)
- Charging time – current and in the future.
- EV turnover time between charging cycles.
- Number of chargers.
- Types of chargers and the granularity or resolution in each power module or combinations of power modules.
- Distributed or integrated charger arrangements
- Site utilisation factor
- Country/location – do some sites require higher/lower diversity?
- Development of technology – future trends, charging speeds, customer's future expectations
- Customer current expectations of power availability.

D. *Electrical Design – Cables*

EVC demand can require substantial electrical power. Cable design follows similar requirements to traditional electrical infrastructure, but the following considerations are worth noting:

- Often large diameter LV cables (240-630mm2) cables are used. Cable support and termination facilities at equipment connections and cable trays are considerable.
- The environment may be more controlled – and cable armouring may not be required if mechanically protected.
- As the EVC demand is not constant, derating factors may be risk assessed.
- Cable routing within public areas may require a different approach to secure industrial sites.
- Bus trunking systems and close coupled switchgear to transformers offer alternative current carrying methods.

E. *Electrical Design - Harmonic Effects*

Power electronic switching generates harmonics that are fed back to the utility supply. The utilities require that the total voltage harmonic distortion at the point of common coupling nearest a customer's point of supply shall comply with certain levels. These vary between utility supplier, standards and countries.

Harmonic levels are required from the EVC OEM to determine the impact back into the grid system.

Harmonic studies may be required to check background harmonic levels, injected harmonic and utility limits.

Filters can be installed to mitigate high harmonics.

F. *Electrical Design - EMC Requirements in The Public Domain.*

EV charger standards [7], [8] describe EMC environments as:

- Residential and Commercial - where LV equipment is connected directly to the LV public mains network.
- Industrial - where LV equipment is connected to a separate, dedicated transformer.

Equipment connected to these power supplies is classed as A or B. [9], [10]

Class A is allowed in a commercial, industrial, or business environment, but not residential.

Class B is suitable for use in residential areas which is assumed to be less controlled and more susceptible to radio reception cross-interference.

High powered DC EVCs are generally Class A. This poses challenges when connecting on a typical forecourt close to residential areas that may share the same LV transformer as shown in the photograph below.

Figure 5 EMC constraints in Residential areas.

G. Remote Monitoring and Control

A complexity often overlooked is managing a very large population of equipment on sites across a wide geography.

Remote monitoring of the status of the EVC performance, circuit breakers, emergency stop, transformer temperature, substation door position, etc. offers useful information to the CPO back office.

Remote control offers a significantly greater opportunity to manage the sites. However, this often comes with increased equipment costs. Motorised circuit breakers, electrically latched equipment and purpose designed circuits may be necessary. This equipment requires more space and increases complexity.

When considering the costs of personnel to commute to the site and re-energise a circuit (typically an incorrectly pushed emergency stop), then remote monitoring and control could become the norm.

Asset and alarm management solutions facilitate these requirements and offer very useful management data for site monitoring, optimisation and improved future designs.

If remote monitoring and control functions are to be implemented, then cyber security measures and other penetration tests need to be implemented and performed to preserve the safety of the whole CPO backend network.

H. Canopy Design

ICE vehicles are usually refuelled under a canopy or roof. EV charging takes a lot longer and drivers request the same protection from the elements. However, canopy designers need to consider the cantilever design support dimensions relative to the EVC bay layout, local ground conditions, wind, snow, solar gain, lighting, number of bays, branding etc.

This can result in significantly high costs which may need to be justified.

I. LV Switchgear Design

The standard IEC 61439-7 [11] defines the requirements of low voltage switchgear and control gear assembly for electric vehicles charging stations (AEVCS). There are three main conditions that differentiate AEVCS from standard LV switchgears and control gears defined in the standard IEC 61439-2.[12]. These include:

- Rated Diversity Factor: For AEVCS the rated diversity factor of the outgoing circuit supplying directly the connecting point shall be taken as equal to 100% (1pu). The rated diversity factor of the distribution circuit supplying multiple connecting points may be reduced if a load control is available.
- Temperature Rise Test: OEM suppliers shall verify that the temperature-rise limits, specified in section 9.2 of IEC 61439-1 for the different parts of the assembly or assembly system will not be exceeded.
  Verification shall be made with one or both of Testing or Comparison with a reference design.
  It is therefore not possible to verify temperature rise test by ‘calculation’ defined in section 10.10.4 of IEC 61439-1.
- Mechanical Strength: As part of IEC 61439-7, all OEM suppliers of AEVCS shall classify their assembly as Basic Resistance, Medium Resistance or High Resistance. They must verify the mechanical strength of the assembly by performing the tests in Table 2.

Name of Test	Basic Resistance	Medium Resistance	High Resistance
Resist to mechanical impact	IK07	IK08	IK10
Resist to static load (evenly distributed load)	No	4500 N/m² shall be applied for 5 min	8500 N/m² shall be applied for 5 min
Resist to static load (lateral force test)	No	600 N applied for 5 min in turn	1200 N applied for 5 min in turn
Mechanical strength of doors	No	A load of 50N + load increase to 450N	A load of 50N+ load increased to 450N
Resist to shock load	No	No	total mass of 15 kg
Resist to torsional stress	No	No	2x1000N applied for 30s
Sharp edged objects	Optional	Optional	Optional

Table 2 Mechanical strength tests of AEVCS

VIII. PAYMENT SYSTEMS

Payment systems are required to facilitate a simple, effortless form of payment from the user. They can be split into two main categories:

- Card present payment (in person) using a payment terminal, credit card, contactless or RFID.
- Card not present payment (digital payments) – mobile or web APPS, QR codes or plug-and-charge.

End-to-end payment solutions comprise of an interface between the user, the payment platform, the acquirer and the merchant (the business).

This all needs to be managed in a highly controlled manner to meet payment card industry (PCI) compliance regulations.

PCI compliance applies to both “card present” and “card not present” transactions. Meeting the PCI requirements between the two is different.

Due to sensitive customer card data – present or not present, payment solutions are required to meet the payment card industry digital security standards (PCI DSS) compliance regulations. Compliance is mandated by card companies and financial institutions to help ensure the security of payment card transactions for both the customer and the merchant. The approach to PCI compliance from a technical and solutions perspective impacts the scope of the PCI requirements. A point-to-point encrypted solution descopes the requirements up to 60% compared to an end-to-end encrypted solution.

Companies need to assign a PCI compliance officer to manage this legal requirement. Internal collaboration with technical and business stakeholders is required to ensure PCI requirements are met.

Standardising payment terminal solutions across the globe is challenging and no single solution exists primarily due to a diverse range of EVC OEMs, acquirers and gateways.

Methods to improve standardisation include:

- Standardise payment protocols with EVC OEMs.
- Standardise on modular hardware with EVC OEMs.
- Standardise on a single cloud-based payment gateway.
- Enable dynamic transaction routing with the gateway.
- Integrate into existing site master data systems.
- Use point-to-point solutions for PCI compliance.
- Integrate into existing acquirers that have certified the payment terminal.
- Integrate with sales enterprise resource planning systems.

The above requirements are onerous for EVC OEMs as different customers have varying needs.

Adopting a cloud level between payment gateway and EVC rather than operating at a local level simplifies matters. However, long integration durations usually result in a more complex, but faster local solution.

The time and cost required to integrate a new payment solution can be significant and delay onboarding an EVC, influence country selection and even EVC supplier. Early engagement of key stakeholders will help manage costs, timelines and solutions when selecting an EVC OEM or deploying in new countries.

IX. CONCLUSION

Knowledge of the “Pertinent P’s” will help engineers working in the EV charging industry.

Understanding the place where site will be located helps determine the feasibility and risks of site selection.

Appreciating the power required for a site and utility supplier requirements will facilitate a smoother project process.

Being familiar with the calibre of people employed to design, construct and operate sites will allow for a safer and better engineered outcome.

Knowledge of the various products employed on sites will allow for optimal selection and utilisation.

Understanding procedures, standards and country requirements are key to any site design.

Appreciating payment requirements, timescales and implications will help determine the optimal equipment and payment solution.

X. NOMENCLATURE

AC	Alternating current.
AEVCS	Assembly for Electric Vehicles Charging Stations
APP	Application or Application program
BESS	Battery energy storage systems
CCTV	Closed circuit television.
CDEGS	Current Distribution, Electromagnetic fields, Grounding and Soil Structure Analysis
CDM	Construction design management
CPO	Charge point operator.
DC	Direct current
DNO	Distribution network operator
EMC	Electromagnetic compatibility
EPC	Engineering, procurement and construction
EPR	Earth potential rise
EV	Electric vehicle
EVC	Electric vehicle charger
EVSE	Electric vehicle supply equipment
GaN	Gallium Nitride
GPR	Ground potential rise.
GRP	Glass reinforced plastic.
HMI	Human machine interface Human machine interface
HV	High voltage
HVAC	Heating, ventilation and air conditioning
ICE	Internal combustion engine vehicle Internal combustion engine vehicle
IGBT	Insulated-gate bipolar transistor.
LV	Low voltage
NVH	Noise, vibration and harshness
OC/EF	Overcurrent and earth fault
OEM	Original Equipment manufacturer.
PCI	Payment Card Industry
PEN	Combined Neutral and Protective Conductor
PME	Protective multiple earthing
QR	Quick Response code
RCBO	Residual Current Breaker with Over-Current
RCD	Residual current device
RFID	Radio Frequency Identification
SiC	Silicon carbide.
TLF	Time limited fuse

APPENDIX A

CONSIDERED DIFFERENCES BETWEEN INTEGRATED AND DISTRIBUTED CHARGERS.

		DISTRIBUTED	**INTEGRATED**
CAPITAL EXPENDITURE	Usage of installed power (charging capacity ratio)	Better use of installed power	Poor use of installed power
	Installed power	Sized for higher number of simultaneous charge sessions	Sized for peak power
	Bill of Materials	Single rectifier per site, single filter per site, and renewable source, additional power distribution (switching matrix)	Individual rectifier and filter per charger point and renewable source
	Wiring infrastructure (For similar voltage AC resistance expected to be larger than DC due to skin effect)	Lower gauge wiring (950VDC) 3 wires: DC+, DC-, PE	Higher gauge wiring (400VAC) 5 wires: 3P, N, PE
	Switchgear	DC switchgear is more expensive and less mature than AC counterparts	Widely available and mature across different industries
	Noise mitigation requirements (charger housing, HVAC)	Less required (noise source away from customer)	More required (noise source close to customer)
OPERATIONAL EXPENDITURE	Charging efficiency	Better use of power modules	Limited use of power modules
	Priority charging	Full dynamic loading capability	Limited dynamic loading capability
	Number of charging sessions	Full dynamic loading capability	Limited dynamic loading capability
	NVH requirements (limited charge rate on quite mode)	Less required	More required
RELIABILITY		Single point of failure (single inverter) Modular Multi Input Multi Output AC/DC/DC/DC improve reliability. Maturity and control of DC switchgear	Large Bill of materials
FUTURE PROOF	Integration to smart grids/Renewable Energy Solutions	Low number of conversion phases	High number of conversion phases
	Scalability	Easy (modularity)	Difficult (less modularity)

TABLE A-1 Differences Between Integrated and Distributed Chargers

XI. ACKNOWLEDGEMENT

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XII. REFERENCES

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