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Guiding infrastructure deployment: the involvement of international standardization

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Abstract

This paper presents the current evolution in the field of charging infrastructure, highlighting the role of international standardization to achieve safety, compatibility and performance. It reports from the frontline of the standardization scene, benefiting of direct feedback from the work of relevant technical committees, as to focus on current evolutions on the global level, to highlight the latest developments and to identify the gaps where further work is needed.

Keywords: standardization, regulation, infrastructure, charging, accessories

1 Generalities

In urban traffic, due to their beneficial effect on environment, electrically propelled vehicles are an important factor for improvement of traffic and more particularly for a healthier living environment. The battery acts as the on-board rechargeable energy storage system (RESS) of the electric vehicle, and has to be supplied with electric energy from the grid. The energy transfer to the vehicle can be conductive (e.g. using a cable); wireless technologies are now also emerging.

The standardization of the electric vehicle is a complex matter due to the electric vehicle uniting both automotive and electrical technologies, the international standardization of which is treated by the international bodies IEC and ISO, respectively. Due to the different cultural approach to standardization in these two technological realms, a consensus had to be established as to the division of the work, with vehicle-centric aspects being dealt with by ISO on one hand and infrastructure-centric aspects and electrical components dealt with by IEC on the other hand. The main responsible committees are TC69 on IEC side and TC22 SC37 on ISO side, several other committees are involved however on aspects such as batteries or accessories making the standardization landscape a complex one as shown in Fig. 1.

Within Europe, a similar situation exists with CEN and CENELEC, for the moment however no separate European standards are being drafted, the work being performed on global ISO/IEC level and the international standards being adopted as European standards. CEN and CENELEC have constituted a joint Electro-Mobility Co-ordination Group, following up the relevant European Union mandates and directives, such as the European directive on the deployment of alternative fuels infrastructure, published in October 2014 [1], and make recommendations accordingly.

2 Conductive charging

2.1 Main standards

The main reference documents for conductive charging are the IEC61851 family of standards. The first part, IEC61851-1, deals with general requirements. First published in 2001, a second edition came in 2010 [2]. Work on the third edition is now ongoing; the complexity of the matter makes this however a long process, with several drafts circulating, and a CDV provided for the Spring of 2015.

Part 21 of this standard initially dealt with vehicle requirements. Since vehicle-related issues are the province of ISO, this matter was transferred however to the ISO17409 project, which is now

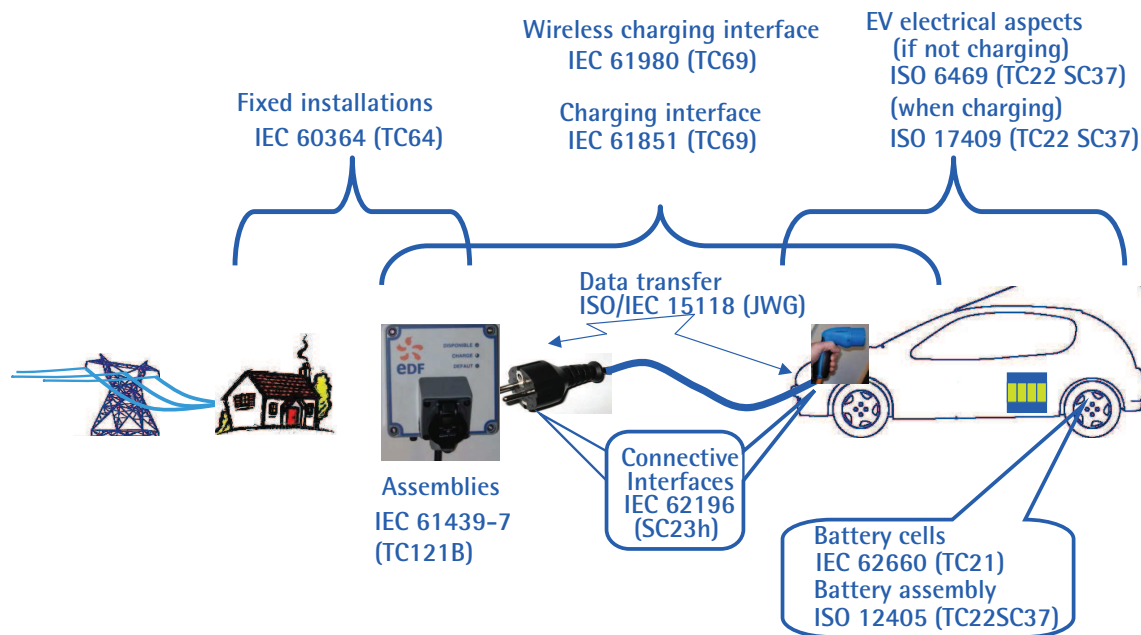


Figure 1: EV standardization scene

circulating as final draft international standard. A clear need was perceived to cover EMC issues for charging. The influence of the extended use of power electronic converters as used in battery chargers will have to be closely followed up in order to avoid potential problems regarding electromagnetic compatibility either in the form of radiated electromagnetic waves or as conducted interference on the interconnecting cables, issues which are not covered by the traditional ISO and CISPR standards for vehicle-related EMC, which focus on radiated emissions and radio disturbances. EMC for charging will be covered by IEC61851-21-1 for on-board charging and by IEC61851-21-2 for off-board charging, both of which are now under development.

The parts 61851-23 and 61851-24, dealing with d.c. charging, were published in 2014. [3, 4]. The specific needs of light electric vehicles will be covered in several standards now classified under IEC61851-3-x. The definition of "light electric vehicle" in this context is more related to the electrical characteristics than to the vehicle itself: the proposed borderline between part 1 and part 3 is for the latter to focus on "d.c. EV supply equipment up to 120V, using class III equipment or reinforced insulation as principal mechanism for the prevention of electric shock".

2.2 Charging modes

One of the basic concept of the standard IEC61851-1 are the so-called *charging modes*.

2.2.1 Mode 1 charging

In *Mode 1* charging, the connection of the EV to the a.c. supply network (mains) makes use of

standard (non-dedicated) socket-outlets with currents up to 16A.

The safe operation of a Mode 1 charging point depends on the presence of suitable protections on the supply side: a fuse or circuit-breaker to protect against overcurrent, a proper earthing connection, and a residual current device (RCD). It is difficult however for the EV driver to easily assess the quality and safety of the electrical installation when plugging in. For this reason, Mode 1 charging is being deprecated, except for light vehicles.

2.2.2 Mode 2 charging

In *Mode 2* charging, the connection of the EV to the a.c. supply network (mains) also makes use of standard non-dedicated socket-outlets. It provides however additional protection by adding an *in-cable control box* (ICCB).

Mode 2 is now generally proposed for convenience charging at non-dedicated outlets. The characteristics of the ICCB are described in the standard IEC62752, under development by IEC SC23E.

2.2.3 Mode 3 charging

Mode 3 charging: involves the direct connection of the EV to the a.c. supply network utilizing dedicated electric vehicle supply equipment. This may refer to both private or public charging stations. The standard IEC61851-1 [2] mandates *control pilot* protection, which has the following functions mandated by the standard:

- verification that the vehicle is properly connected

- continuous verification of the protective earth conductor integrity
- energization and de-energization of the system
- selection of the charging rate (ampacity)

This function is typically performed through an extra conductor in the charging cable assembly, in addition to the phase(s), neutral and earth conductor. Annex A of IEC61851-1 (published as technical specification IEC/TS62763 [5] pending publication of third edition of 61851-1) specifies the control pilot circuit. A control signal is sent through the control pilot conductor. When no vehicle is connected to the socket-outlet, the socket is dead; power is delivered only when the plug is correctly inserted and the earth circuit is proved to be sound. The control signal is 1kHz PWM, with the duty cycle allowing ampacity control, the charging station informing the vehicle of the maximum allowable current.

The inherent safety features, as well as the potential for smart grid integration, make Mode 3 the preferred solution for public charging stations as well as for home charging using dedicated outlets. [6].

2.2.4 Mode 4 charging

In *Mode 4* charging, the vehicle is indirectly connected to the a.c. supply network (mains) utilizing an off-board charger. This pertains to d.c. charging stations, which are mostly used for fast charging. As the charger is located off-board, a communication link is necessary for regulated d.c. charging stations to allow the charger to be informed about the type and state of charge of the battery as to provide it with the right voltage and current.

2.3 Accessories for charging

Conductive connection makes use of the following accessories:

- on the vehicle side, a *vehicle inlet* and a *connector*
- on the charging station side, a *plug* and a *socket-outlet*

The cable and plug may be permanently attached to the vehicle (case "A", generally found only in very light vehicles), a detachable cable can be used (case "B", the most common for normal and semi-fast charging), or the cable and connector can be permanently attached to the supply equipment (case "C", typically used for fast charging where heavy cables are used, but posing a higher risk of copper theft for public use).

2.3.1 Standard accessories for Mode 1 and 2

For Mode 1 and Mode 2 charging, standard plugs and socket-outlets can be used. Domestic accessories however are not really suited for the

heavy-duty operation of electric vehicle charging, characterized by long time operation at near rated current and frequent operation, including disconnection under rated load. This leads to a shorter lifetime of the accessories and to contact problems which may cause hazardous situations. It is thus recommended to limit the rating of the charging equipment using such plugs to a lower value, up to 10A, their use being confined to small vehicles such as scooters (for which this current level is largely sufficient), as well as for occasional charging of larger vehicles (the "grandma" solution). The limit of 10A is typical for Mode 2 ICCB cables as delivered with most electric vehicles. Some countries use even lower values such as 8A.

A better alternative for Mode 1 or Mode 2 is to use industrial plugs and sockets as defined by the international standard IEC60309-2 [7]. These plugs (in standard blue colour for 230V, red for 400V) are widely used, particularly in Europe, for industrial equipment but also for outdoor uses like campsites, marinas, etc.

2.3.2 Dedicated accessories for a.c. charging

The use of a physical control pilot conductor necessitates the introduction of specific accessories for electric vehicle use. Such plugs and sockets are described in the international standard IEC62196 "Plugs, socket-outlets, vehicle couplers and vehicle inlets - Conductive charging of electric vehicles". Part 1 of this standard [8] gives general functional requirements; physical dimensions for a.c. accessories are treated in part 2, was published in 2011 [9]. It does present standard sheets for several types of connectors, vehicle inlets, plugs and socket-outlets:

- **Type 1**
The Type 1 single phase coupler (Fig. 2) is rated for 250V and 32A, allowing a.c. charging at up to 7kW. This solution is featured in SAE-J1772 [10] and based on a proposal made by the Japanese company Yazaki. It is intended to be used as vehicle connector/inlet only, there is no corresponding plug as US charging stations typically work with a Case "C" connection only.



Figure 2: Type 1 connector

- **Type 2**
Type 2 is a three-phase accessory rated for currents up to 63A, and has two auxiliary

contacts. With three-phase charging at this current, fast a.c. charging can be achieved at power levels exceeding 40kW. It is illustrated in Fig. 3 and based on a realisation by the German company Mennekes. The need for three-phase accessories was expressed by European car manufacturers and utilities, recognizing the potential benefits of three phase charging and the availability of three phase supply in most European countries. Type 2 also features a connector/vehicle in-



Figure 3: Type2 plug

let combination (similar but not interchangeable with the plug/socket-outlet). The automobile industry is presently mounting both Type 1 and Type 2 inlets on cars and light trucks, depending of the original market of the vehicle. In Europe, both types can thus be found.

- Type 3
Type 3 is also a three-phase type, based on a design by Italian company SCAME further adopted by the "EV Plug Alliance".

The choice of a single type plug (either Type 2 or Type 3) for European charging stations has been a point of discussion. One main difference between Type 2 and Type 3 accessories is the presence of "shutters" on the latter which may be required in some countries by national wiring regulations for socket-outlets in domestic environments. However, shutters are now also available for Type 2.

Since the new European directive on the deployment of alternative fuels infrastructure [1] prescribed the use of Type 2 accessories as the standard solution for Europe, Type 3, which was used in France and Italy only, is thus gradually phased out.

2.3.3 Connectors for d.c. charging

Connectors and vehicle inlets for d.c. charging are treated in IEC62196-3 [11]. The standard presents three families of connectors: the "CHAdeMO" type of Japanese origin (Fig. 4), the "Combo" type encompassing both a.c. (Type 1 or 2) and d.c. inlets in one unit (Fig. 5), and a third connector type mainly used in China. The latter has not been adopted in the European version of the standard, the standard sheet being not applicable in Europe.

The new European directive [1] prescribes the use of "Combo type 2" connectors for d.c. fast

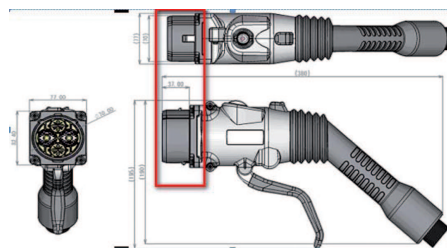


Figure 4: CHAdeMO connector

charging stations. However, due to the presence of the market of large numbers of electric vehicles of Japanese origin, the "CHAdeMO" type will also co-exist with the "Combo" for a considerable time.



Figure 5: Combo connector example

There is still some discussion within the standards committees regarding the use of Type 2 connectors system with commutable a.c./d.c. pins, as shown for example in Fig. 6. This combined use of a.c. and d.c. on the same pins has however given rise to safety concerns particularly from the electrotechnical industry, where the switching of contacts between a.c. and d.c. is not common practice. The injection of d.c. fault currents into the a.c. grid must in fact be impeded in all cases, as the a.c. circuit breakers will not be able to interrupt these d.c. currents.

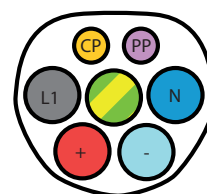


Figure 6: Combined use of Type 2 connector

3 Wireless charging

Wireless charging dispenses with the use of cables and connectors. The wireless energy transfer between the vehicle and the charging point can be performed in several ways:

- inductive, through magnetic fields
- capacitive, through electric fields

- microwave, through electromagnetic radiation

The latter two techniques are still in an early experimental stage and any standardization work is still under consideration; significant technological development has taken place however on inductive charging.

The introduction of inductive charging systems has been proposed to allow a considerable improvement of charging safety. The non-conductive energy transfer virtually eliminates all risk of electric shock for the user. Furthermore, the opportunity for automatic connection dispenses with the use of electric cables, thus removing both electrical (handling of power connectors,...) and mechanical (trailing cables,...) hazards which are usually associated with the use of electric vehicle charging equipment.

One type of inductive charging has been introduced and extensively promoted by General Motors in the 1990s. The secondary coils were arranged around a slot in the vehicle, the primary coil being a paddle to be inserted in the slot. This approach, still needing a cable, has been abandoned.

New developments for wireless charging will make use of automatic systems operating when the car is parked, or even dynamically during driving on an adapted road.

Standardization for an emerging technology such as wireless charging presents several challenges. Whereas the development of new technologies may be hampered by premature implementation of restrictive technical and dimensional standards, the early availability of sound safety standards will form a strong guideline supporting development.

The international standardization work on wireless power transfer systems (WPT) has been revived and documents are being developed in the IEC61980 series.

- The first part of this standard, now circulating as final draft international standard (FDIS), deals with general requirements, including general background and definitions, as well as safety requirements. Part 1 is general, and not technology-specific.
- Part 2, now in committee draft stage (CD), covers specific requirements for communication between EV and WPT systems.
- Part 3, also in CD stage, covers specific requirements for magnetic field wireless power transfer systems, i.e. inductive chargers. Several implementations are described in the annexes to this part in order to ensure interoperability.

4 Battery swapping

Fast replenishment of the energy on board of the vehicle can be performed by swapping the battery pack with a freshly charged one. This technology, which has been used in the past for niche

applications such as industrial electric vehicles, has now gained new interest for general use. Its implementation however will entail specific standardization problems.

Standardization work on battery exchange has been taken up in 2012 with a the IEC62840 family of standards "Electric vehicle battery swap system". At present, two documents in this series are being circulated as committee drafts:

- Part 1, giving general requirements, definitions and use cases
- Part 2, focusing on various safety requirements

5 Communication standards for charging

5.1 Basic communication

The communication between the vehicle and the charging post can be developed in several ways, with increasing sophistication. In Mode 1 or Mode 2 charging, where standard non-dedicated socket outlets are used, there is no communication with the charging post. Mode 3 introduces communication through the control pilot function, with ampacity control conveyed by the pulse-width modulation (PWM) pilot signal. This feature presents several operational benefits: the charger can adjust itself to the maximum allowable current that can be delivered by various charging points, and the charging point can control the amount of current absorbed by the charger, in the framework of a smart grid load management or to optimize the tariffication of the electric energy.

Mode 4 off-board chargers, which supply a direct current to the vehicle battery, must communicate with the vehicle in order to supply the battery with the correct voltage and current. This is treated in the new standard IEC61851-24 [4], defining the messages of digital/data communication to be used during charging control between off-board d.c. charging system and electric road vehicle.

5.2 High-level communication with the charging post

High-level communication between the vehicle and the charging post is being addressed by a joint working group uniting ISO and IEC, drafting the ISO/IEC15518 family of standards "Road Vehicles - Vehicle to grid communication interface", treating the communication between the electric vehicle and the electric vehicle supply equipment (charging post).

Part 1 "General information and use-case definition" [12], provides a general overview and a common understanding of aspects influencing the charge process, and contextualizing all envisageable charging processes in so-called "use cases" in order to define communication needs.

The second part, describing the technical protocol, was published in 2014 [13], subsequent parts are under development on the physical and data link layer requirements (15118-3), as well as test procedures (15118-4, -5) and provisions for wireless communication (15118-6, -7, -8).

5.3 External communication

ISO/IEC15118 only deals with the communication between the vehicle and the charging post. Other actors are however involved in the communication process (back-office, grid management, ...), as shown in Fig. 7. This is particularly the case where smart-grid or bidirectional power transfer ("vehicle to grid") are envisaged. Such activity will likely make use of existing physical protocols, there may however be a need to standardize the data structures in order to ensure interoperability.

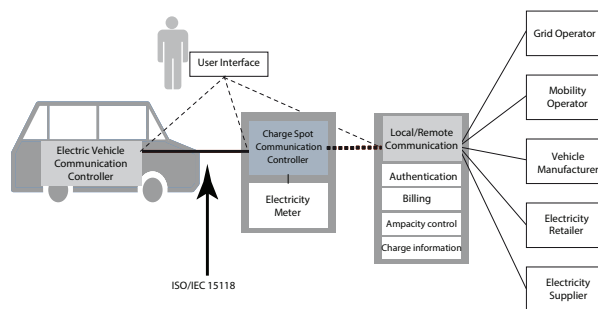


Figure 7: Communication actors

At this moment, no international standardization work is being performed yet, some new work items have been proposed however. This work will need to be performed in close collaboration with other interested committees and may incorporate existing consortium projects such as the Open Charge Point Protocol [14] to the level of an international standard document.

6 Conclusions

The charging of electrically propelled vehicles remains a key issue for future standardization work. As with all standardization matters, charging standards incorporate the three main pillars of the house of standardization: safety, compatibility and performance.

Safety standards ensure protection against electric shock and other related hazards, as well as controlling electromagnetic compatibility issues, allowing the charging infrastructure to be used safely in all its potential environments.

Compatibility standards obviously refer to the definition of suitable plugs and sockets for electric vehicle charging, but also cover the communication needs of charging and allow the electric vehicle to be deployed in an extended area and the infrastructure to be universally usable.

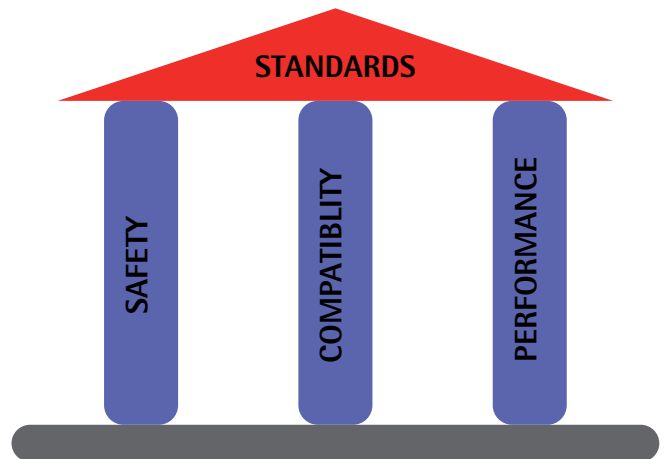


Figure 8: The House of Standardization [15]

Performance measurement standards, in the framework of this study, pertain to the management of energy measurement for billing as well as battery state of charge and state of health. Worldwide, experts are working together to draft these standards, overcoming technical and cultural differences in order to allow unified solutions, with a clear final objective: to allow every electric vehicle to charge safely anywhere. Standards are a key factor in allowing the deployment of electrically propelled vehicles on a global level, and the example of the electric vehicle is an ideal showcase to highlight the technical and societal relevance of standardization.

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