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International standardization of charging infrastructure: achievements and new developments

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Abstract

The international standardization scene for vehicle charging infrastructure is still in full development. Besides the long-awaited publication of the basic IEC61851-1 standard, new developments are taking place both on the higher and lower limits of the power envelope, thus considering both heavy-duty vehicles and light vehicles. The multitude of players in the field makes the whole evolution challenging however. The paper highlights ongoing developments, giving the latest news from the standardization shopfloor.
Keywords: standardization, RCS, infrastructure, standards.

1 Introduction

In urban traffic, due to their beneficial effect on environment, electric vehicles are an important factor for improvement of traffic and more particularly for a healthier living environment. Electric vehicles need an appropriate charging infrastructure for their energy supply, and this infrastructure needs international standards to allow safety and interoperability. The standardization work is mainly done within IEC regarding the infrastructure issues, with specific vehicle-based aspects covered by ISO.

This division of labour between the two organizations has not always been straightforward. International standardization for electric vehicles started already in the 1970s [1], with both IEC and ISO trying to cover the whole subject. Collaboration was sometimes not very smooth, also due to the different standardization culture in the electrotechnical sector versus the automotive sector, and the different background of experts seating in the respective committees.

By the end of the 1990s, the division of labour was made clear, with ISO (TC22 SC21, later SC37) covering the vehicle-related aspects and IEC (TC69) covering electrical aspects including charging infrastructure. IEC TC69 is thus the main committee dealing with charging infrastructure standards.

2 Conductive charging

The main standard relating to conductive chargingd is the IEC61851-1 [2], the third edition of which was issued early 2017, with the maintenance procedure already starting late 2017. This document gives the general requirements that serve as a basis for all the subsequent standards in the series. encompassing mechanical, electrical, communications, EMC and performance requirements for EV supply equipment conductively connected and used to charge electric vehicles. The aspects covered in this standard include the characteristics and operating conditions of the EV supply equipment, the specification of the connection between the EV supply equipment and the EV, the requirements for electrical safety for the EV supply equipment, the connection to fixed installations and requirements for basic communication for safety and process matters if required.

One main concept introduced by IEC61851-1 are the so-called ”charging modes”, defining the way of connecting the electric vehicle to the supply network:

- Mode 1, now deprecated, covers the direct connection of the EV to the AC supply network, using any non-dedicated outlet
- Mode 2 connects to the supply network using an in-cable control and protection device (IC-CPD) as described in IEC 62752 [3]. An IC-CPD cordset is typically delivered as an accessory to the electric vehicle, enabling charging at a non-dedicated socket-outlet when no charging station is available.

  Domestic accessories not being designed however their maximum current (16A) during a long period (several hours), most mode 2 IC-CPD limit the current to typically 10A (in some countries 8A), corresponding to a power of maximum 2,3kW.

  This rather modest power level limits the attractiveness of Mode 2 to occasional or emergency charging. It is not suited for public charging infrastructure.
- Mode 3 involves the direct connection of the EV to the a.c. supply network utilizing dedicated electric vehicle supply equipment. This mode can be used for both private and public charging stations.

  The standard IEC61851-1 [2] mandates additional protection measures to be provided by the so-called *control pilot*, a device which has the following mandatory functions:

  - 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 specifies the control pilot circuit given in fig. 1, showing the operation of the system. A control signal (1 kHz PWM) is sent through the control pilot conductor. The switch on the vehicle allows to control the charging, whileas the duty cycle of the PWM signal, generated by the charging station, indicates the maximum charging current to the vehicle, thus allowing dynamic power control.

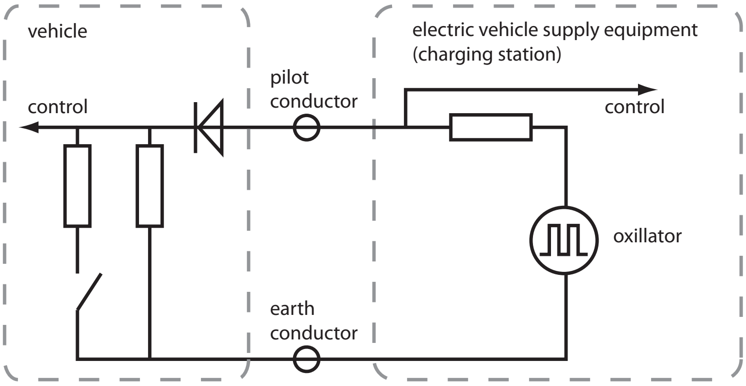

Figure 1: *Control pilot conductor*

  When no vehicle is connected to the socket-outlet, the socket is dead. This provides a key safety advantage particularly for publicly accessible charging points. Power is delivered only when the plug is correctly inserted and the earth circuit is proved to be sound.

  These inherent safety features, as well as the potential for smart grid integration (dynamic setting of the maximum current rate by the charging station), make Mode 3 the preferred solution for a.c. charging, it is thus supported by virtually all electric vehicles on the market worldwide.
- Mode 4 relates to DC charging using an off-board charger. The requirements for Mode 4 connection are described in IEC61851-23 and -24 [4, 5], now under revision.

3 Accessories

3.1 AC charging

The control pilot used for Mode 3 charging necesitates an extra conductor. New accessories with extra pins had thus to be developed for this purpose. The general requirements for EV accessories are given in IEC62196-1 [6] whileas accessories for a.c. charging are described by IEC62196-2 [7].

The latter standard describes three families of accessories.

3.1.1 Type 1 accessories

Type 1 is a single-phase vehicle coupler rated 250V, 32A.
It corresponds to the SAE J1772 coupler [8] and is widely used on electric vehicles of American or Japanese origin. It is the most widespread coupler for EV charging infrastructure in the United States, as a *de facto* but not official national standard.
Note that the standard only considers Type 1 vehicle connectors and vehicle inlets. The use of Type 1 accessories on the charging post side (plug and socket-outlet) is not foreseen in the standard. This reflects the fact that in the United States only Case "C" is used, with the cable fixed to the charging station, and there is no need for a plug.
Two additional contacts are present in the connector: one for the pilot function (according to Annex A of IEC61851-1 [2]) and one for the proximity function, defined as an electrical or mechanical means to indicate the insertion state of the vehicle connector in the vehicle inlet to the EV.
In the USA only, the Type 1 can be rated 80A according to a country note in IEC62196-2 [7].

Figure 2: *Type1 vehicle connector engaged (cover of CHAdeMO d.c. inlet to the left)*

3.1.2 Type 2 accessories

Type 2 accessories originated from Germany and are widely used in electric vehicles of European origin. They are rated for 480V, 63A three phase or 70A single phase.
Interlocking of these accessories is mandatory and is integral to the design. Plug and socket-outlet, as well as vehicle connector and vehicle inlet, are locked during the charging process. This interlocking prevents unintentional or unauthorized separation and supports both:

- *safety*, as to prevent disconnection under load which may cause arcing
- *security*, as to prevent cable theft (particularly in Case "B") or unauthorized disconnection

The Type 2 comes both as vehicle coupler (connector and vehicle inlet) and as plug/socket outlet. Although the plug and the vehicle connector look similar, they are not intermateable.
The accessories feature two additional contacts: one for the pilot function (Annex A of IEC61851-1) and one proximity contact (Annex B.2 of IEC61851-1). The latter is connected to the earth via a resistor inside the plug or connector, and its function is to indicate the ampacity of the cable In a Case "B" configuration, it may in fact happen that the maximum current communicated by the vehicle to the charging station through the control pilot exceeds the maximum current of the cable.
The European directive 2014/94 on the deployment of alternative fuels infrastructure [9] has prescribed the use of Type 2 for a.c. charging points in Europe, with charging points fitted with a Type 2 socket outlet. Vehicles fitted with a Type 1 inlet can access these charging points using a Type 2 plug / Type 1 connector cable.

3.1.3 Type 3 accessories

Type 3 was developed in France and Italy and is also a three-phase coupler rated up to 32A. It is however fitted with shutters as to comply to French and Italian domestic wiring regulations.
Due to the European directive [9] prescribing the use of Type 2 for a.c. charging points in Europe, Type 3 is considered obsolescent and will be gradually phased out.

Figure 3: *Type2 vehicle connector engaged*

Figure 4: *Type2 plug at charging post*

3.2 DC accessories

3.2.1 IEC62196-3

Whileas the public AC charging infrastructure in Europe is pretty well standardized on the Type 2 accessories, a greater variety exists for DC charging, where three families of accessories are described in the IEC62196-3 standard ([10]. Note that DC charging always uses case ”C” with cables attached to the charging station. The accessories are thus connectors and vehicle inlets.

- CHAdeMO couplers (fig. 5), mostly found on vehicles of Japanese origin
- CCS (Combo) couplers, mostly found on vehicles of European origin. This coupler consists of two DC contacts placed underneath the AC inlet which can be either type 1 or type 2. The pilot contact is used for communication.
- Chinese GB/T20234.3 coupler (not used in Europe)

Due to the various types of vehicles present on the European market, fast charging stations are mostly equipped with both CHAdeMO and CCS connections, often also with a high power AC connection (43kW over Type 2 connector).

3.2.2 Common use of pins

The common use of coupler pins for both AC and DC, allowing to use the compact Type 2 inlet for DC fast charging (fig. 6, is still under discussion and not yet defined in the standards, the concept being hard to accept for the electricity sector where this practice is quite new and its behaviour under fault conditions is considered, fearing the presence of DC fault currents in the AC network, that the AC protective devices in fixed installations are not designed for.
However, the common use of pins has been successfully implemented by Tesla in Europe (in US, Tesla is using proprietary accessories), where the same vehicle inlet is used both for single or three-phase AC charging using a standard Type 2 connector and for DC fast charging at Tesla’s own chargers (or

Figure 5: *CHAdeMO connector engaged*

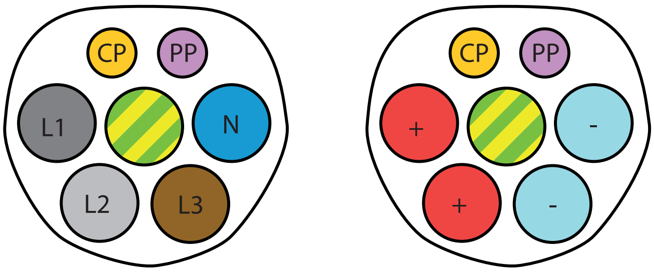

Figure 6: Type 2 accessory (left) used for d.c. (right)

at a CHAdeMO charging using an adapter). The vehicle inlet is compatible with IEC62196-2 Type 2 connectors for AC, but is designed for higher currents than the standard rating Type 2 accessories as described in IEC62196-2. The connectors used for DC also are made for this higher current.

4 The quest for higher power

The DC charging accessories of IEC62196-3 are rated up to circa 50kW. In order to accommodate the needs of heavy-duty vehicles like buses, where the cumbersome manipulation of heavy cables is to be avoided at intermediate charging stops, automatic connection systems (such as pantographs) are being considered. Their characteristics are subject of the new standard IEC 61851-23-1 under development [11]. The charging protocol (with off-board charger) is similar to IEC61851-23. This document does not define the physical interface however, which will be covered in a separate document, now proposed on European level.

There is a demand however for really high power charging (hundreds of kW) exceeding the envelope considered by 61851-23, not only for buses also to allow ultra-fast charging of cars. This issue will involve several other committees (including TC20 for cables and SC23H for accessories, which will have to be designed to take the strain). For example, cooling of connectors and cables will be necessary in order to limit cross-section (and thus size and weight) to a manageable level. An ad-hoc group is constituted by TC69 to cater this issue. The impact of such high-power devices on the grid shall also be taken into consideration.

The issue of bidirectional power transfer (e.g. vehicle-to-grid) is also under consideration and has not been addressed yet.

5 Charging of ”light electric vehicles”

The standardization of charging infrastructure for ”light electric vehicles” is dealt with by the working group WG10 within TC69. The documents of the 61851-3 series are to be circulated as technical specification late 2017.
One of the main issues in this field is the definition of the concept ”light electric vehicle”. It is not easy to base this on vehicle categorization (number of wheels, mass, speed,. . .), as type approval regulations are strongly country-dependent. As the first objective of this standardization work is electrical safety,

the scope of the standards will focus not on vehicle type, but on the electrical characteristics of the connection with protection against electric shock being provided by a system of double or reinforced insulation between all AC and DC inputs and outputs of the EV power supply equipment, or by galvanic separation. This corresponds to *class II* devices, contrary to the *class I* devices treated in 61851-1 where a protective conductor is used to provide electric shock protection.

6 Communication issues

Characteristics of the communication between vehicle and charging posts are described in the family of standards ISO/IEC15118, several parts of which have been published under the aegis of ISO TC22 SC31 ([12, 13, 14]).
Yhe communication between the charging post and the back-office however has not been covered by international standards up to now, with some consortia standards seeing a widespread use such as the Open Charge Alliance (OCA)'s Open Charge Point Protocol (OCPP) [15]. The new edition of the OCPP will be developed under the aegis of IEC TC69 within the project IEC63110 ”Protocol for Management of Electric Vehicles charging and discharging infrastructures” , the work on which as started in 2017, under liaison with the OCA. IEC63110 will address the requirements and information exchange to cover the communication flows between the different e-mobility actors as well as data flows with the electric power system. As this issue includes a strong interaction with the ”smart grid”, a joint working group (JWG11) with IEC TC57 has been established. Furthermore, WG9 within IEC TC69 deals with ”Electric vehicle roaming service”.

7 Wireless power transfer

Standards for wireless power transfer (”inductive charging”) are prepared in the IEC 61980 family. Part 1, giving general requirements (including safety) was published in 2015 [16], the subsequent parts are still under preparation will be published in a first phase as Technical Specification (TS) which allows to expedite the process. Part 2 (specific requirements for communication between EV and infrastructure) was circulated September 2017 as DTS [17] whileas the DTS for Part 3 (Specific requirements for the magnetic field wireless power transfer systems) is expected late 2017, the document still being in CD stage [18]. This work is dealt with by WG7 within IEC TC69.

8 Conclusion

The development of performant charging networks is a key element accompanying the growing deployment of electric vehicles, as to maximize user convenience and flexibility, doing away with range anxiety and facilitating EV ownership for users not having access to private charging facilities. Standardization is essential here, with the case of charging infrastructure clearly epitomizing the main pillars of standardization – safety, compatibility and performance – as represented in fig. 7. Standard solutions have been developed on a global level and are backed by regulatory instruments such as EU Directives. A number of issues still have to be resolved however, such as the coexistence of parallel solutions for DC charging, to reach the ideal of global standard solutions optimally covering user needs and fulfilling the highest safety requirements.

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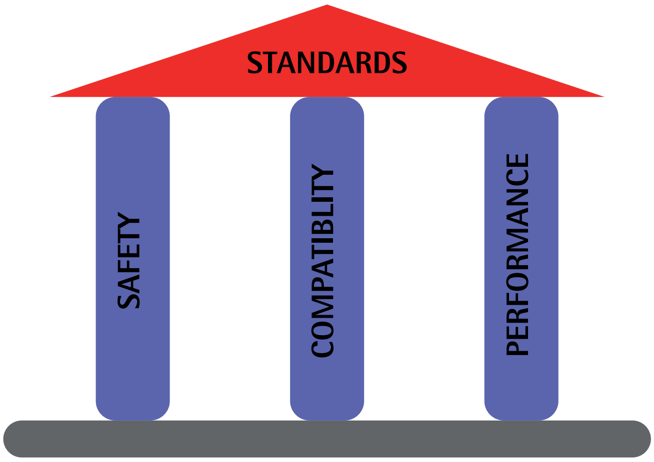

Figure 7: The House of Standardization [19]

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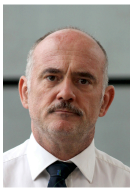

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