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Developments and Challenges for EV Charging Infrastructure Standardization

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Abstract

Although charging infrastructure standardization has come a long way and publicly accessible infrastructure has been deployed in several countries, the standardization process is still going on and several issues remain open. This article aims to highlight current activities in the field on global and European levelnl analyzing the described projects.

1 The current state of standardization

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. The successful global deployment of the electric vehicle is dependent on the availability of international standards; on a global level, standards for electric vehicle charging infrastructure are prepared by IEC TC69, whileas the accessories are dealt with by IEC SC23H. The standard's third edition (IEC 61851-1) is nearing publication, with the FDIS expected in the summer of 2016 [1]. This part states general requirements for conductive charging and defines among others the "charging modes":

- Mode 1 charging, where 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.
- Mode 2 charging, where the connection of the EV to the a.c. supply network (mains) makes use of standard non-dedicated socket-outlets. It provides however additional protection by adding an *in-cable control box* (ICCB).
- Mode 3 charging, involving 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 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)
- Mode 4 charging, where 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.

  The standards for d.c. charging (IEC61851-23 [2] and -24 [3]) were published in 2014 and are under maintenance.

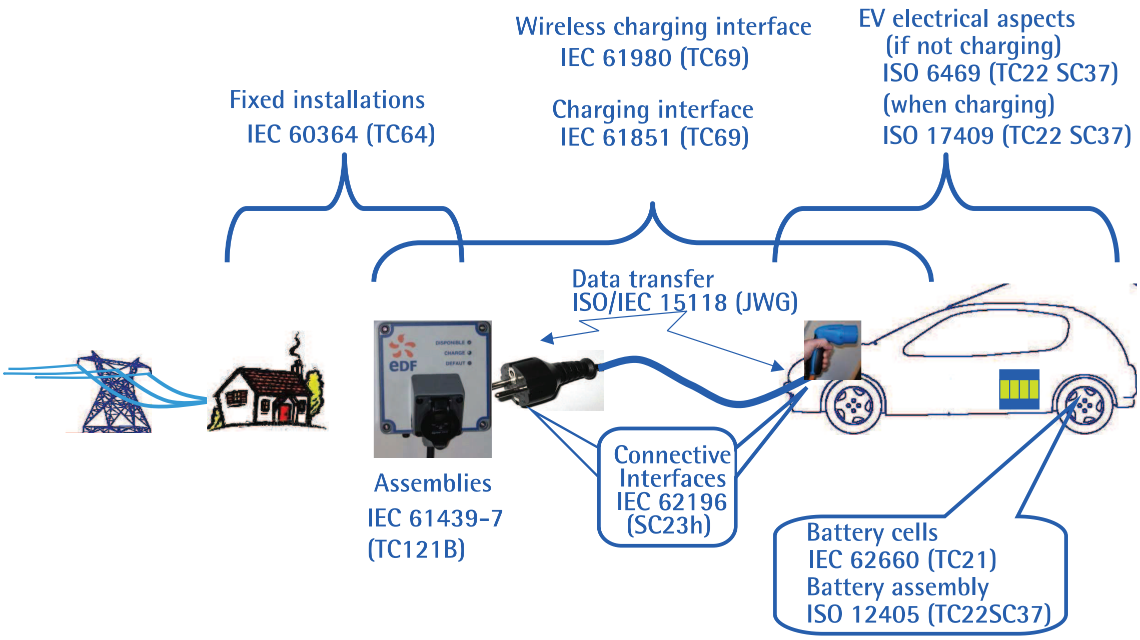


Figure 1: EV standardization scene

Accessory standards have been published in the IEC 62196 series ([4, 5, 6]).

Work is also ongoing for wireless charging (IEC 61980 series) and for light electric vehicles (IEC 61851-3 series). Most documents in this series will, in a first time, being published as Technical Specifications. A TS is not a full-blown standard but can be published faster, allowing the availability of a published document as reference pending the development of a final standard. Such procedure may be beneficial to standardize evolving new technologies.

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. Whereas automotive manufacturers are traditionally vertically integrated and less dependent on external component suppliers and standards, the electrotechnical world has a longer and stronger tradition of standardization, with the IEC being constituted in the first decade of the twentieth century. 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.

2 A.C. charging

For conductive a.c. charging, the use of dedicated accessories according to IEC62196-2 for Mode 3 charging (according to IEC 61851-1) is now well established. American and Japanese vehicles come with Type 1 inlets, whileas the Type 2 inlet is more common on European vehicles.
On the wall side, American charging points come with fixed cables (case "C"), so no plugs or socket-outlets are used. In Europe however, plugs and socket-outlets (case "B") are found. Case "C" charging points with attached cables are generally used only in private premises. High-rate fast a.c. charging stations (43 kW) however are always case "C" due to the heavy cables involved.

The Type 2 plug and socket-outlet is now in general use in Europe, being prescribed by the European directive on alternative-fueled vehicles [7] . Type 3 accessories knew some development in France and Italy, due to the presence of "shutters", required by local wiring regulations for the domestic environment. Following the European directive, Type 3 will be phased out. It is still widespread in France though. Shutters are not strictly needed for Mode 3 charging, as the socket is always dead when no vehicle is connected; where regulations enforce them, they can also be provided on Type 2 accessories.

The Type 1 connector allows single-phase charging up to 32A, corresponding to a power of 7 kw.

The Type 2 accessories can be used for single-phase charging (3 to 7 kW) as well as three-phase charging; with three-phase supply being widely available in European electricity distribution systems, this allows easy semi-fast charging at 22 kW (3×32 A) or even fast charging (case ”C” only) at 43 kW (3×63 A).

For opportunity charging where no Mode 3 outlet is available, Mode 2 cables with in-cable control box are used, these are mostly limited to 10 A as not to overload domestic socket-outlets which are not designed to deliver their maximum rated current (16 A) for several hours[8]. The Mode 2 ICCB devices are described in the international standard IEC62752 [9] developed by IEC SC23E.

On the supply side, IEC60364-7-722 [10] was published in 2015. This document gives particular requirements for circuits intended to supply energy to electric vehicles, as well circuits intended for feeding back electricity from electric vehicles into the supply network, the latter being still under consideration. Wireless charging is not covered.

3 D.C. charging

For d.c. charging (generally fast), several systems co-exist, all making use of case ”C” connections. The charging system is described in IEC 61851-23, with IEC 61851-24 dealing with specific communication issues and IEC 62196-3 defining the accessories. There are three, mutually incompatible, systems defined in these standards: the Japanese ”CHAdeMO” with a dedicated d.c. inlet, the European ”Combo” with a combined inlet which also accepts Type 2 (or Type 1) connectors for a.c. charging, and a third system used in China. This third system is not applicable in Europe.

The European directive [7] prescribes the adoption of ”Combo type 2” accessories for fast d.c. charging in Europe. However, with large numbers of CHAdeMO-equipped vehicles in use, both systems will have to co-exist. Considering also the use of Mode 3 a.c. fast charging (43kW) by some vehicles, public fast charging stations in Europe are now being deployed as multi-mode devices with three outlets, adding considerably to their cost.

A new development however is the use of Type 2 accessories for both a.c. and d.c., with pins commutable for either a.c. or d.c. use (Fig.2). This allows a smaller vehicle inlet to be used. The system has been supported by German car manufacturers and may be introduced as an amendment in future revisions of IEC62196.

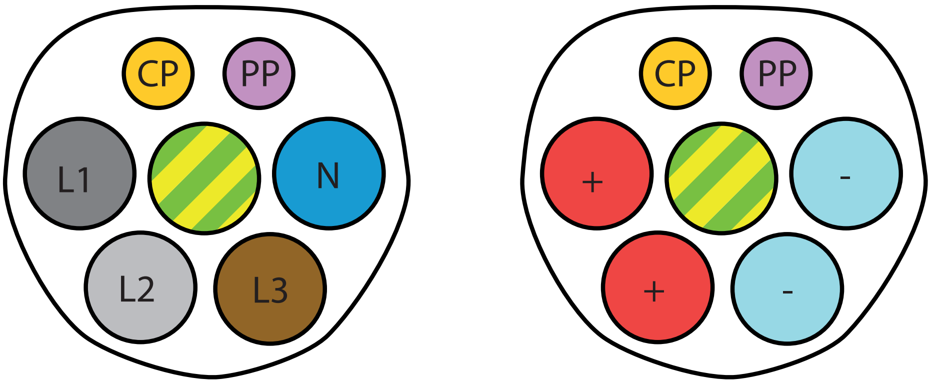


Figure 2: Type 2 accessory (left) used for d.c. (right)

This system is now already in use however for Tesla vehicles on the European market. These are fitted with a Type 2-sized inlet accepting a.c. charge from a standard Type 2 connector, allowing the vehicles to access standard charging points Europe-wide. The same inlet is used however for d.c. charging at Tesla’s proprietary ”supercharger”, with the a.c. pins are used (two in parallel) for d.c., at a rating exceeding the standard rating for IEC62196-2 accessories. The inlet may in fact be 62196-sized, but it is higher rated due to special non-standard construction. In the US, Teslas come with a propietary non-standard inlet. There exists however some reserve towards the commutable pin concept, particularly from the electricity sector. There is in fact fear for a fault condition which may occur when d.c. fault currents are injected in the a.c. mains, where the a.c. circuit breakers are not able to deal with d.c. currents.

New developments in d.c. charging standardization also focus on automatic connection systems which are particularly useful for heavy-duty vehicles such as buses. A new project, IEC61851-23-1, has been started up to this effect in 2016.

4 Light electric vehicles

Light electric vehicles such as two-wheelers may usually charge from standard domestic socket-outlets (Mode 1), but they possess their own safety issues, taking for example into account the fact that many chargers for electric bicycles are designed as domestic appliances for indoor use only. To this effect, new standards for charging light electric vehicles are now being prepared in the IEC 61851-3 series, with the corresponding accessories treated in IEC 62196-4. These documents will be firstly published as Technical Specification.

The main issue on what consists a ”light” electric vehicle, and thus which standard is applicable to its charging, either 61851-1 or 61851-3, discussions are still ongoing concerning the exact scope of these standards. Rather than considering the mass or the registration category of the vehicle proper, the division is likely to focus on the electrical characteristics of the connection, with ”light” electric vehicles either making use of reinforced insulation for protection against electric shock (Class II equipment) or using a d.c. input voltage of less than 120V.

5 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 [11], subsequent parts are still under preparation. As the technology is still evolving and as not to stifle its development while having relevant documents available in a short timespan, these documents will in a first phase be published as Technical Specification (TS) which allows to expedite the process. Relevant parts include IEC61980-2, dealing with specific requirements for communication between electric road vehicle and infrastructure with respect to wireless power transfer systems, and IEC61980-3, giving specific requirements for the magnetic field power transfer systems. The latter document defines among others the geometry of the systems and is thus essential for interoperability.

6 EMC

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.

7 Specific European issues

7.1 European standards

European standardization is dealt with by CEN and CENELEC, which represent the European pendant of ISO and IEC. As such, these organisms are independent and are not part of the EU administration. Standardization for electric vehicle infrastructure is dealt with by technical committee CENELEC TC69X.

Taking into account the global market however, TC69X generally avoids to draft specific separate European standards on its own, preferring to expedite the adoption of published IEC standards as European EN standards. This avoids double work which is inefficient and may lead to conflicting documents.

The adoption of an international standard as European standard involves the creation of a cover page with normative references to corresponding European standards, and with specific country notes, if any. For those standards referring to issues covered by European ”New Approach” directives (this is for example the case for the 61851-1 facing the Low Voltage Directive [12]), the preparation of a so-called Annex ”ZZ” shall be provided, stating the relationship between the standard and the essential (safety) requirements defined in the directive. Conformity with the standard can thus imply presumtion of conformity with the directive. This ”New Approach” is now generally followed for most applications in the European Union, with exception however of vehicle type approval which is dealt with by United Nations (UNECE) regulations.

7.2 Influence of EU policy on standardization

As the executive branch of the European Union, the European commission issues mandates to the European standardization bodies CEN and CENELEC, who are responsible to publish relevant European standards, to be referred to as harmonized standards in the EU directives. In this framework, mandates have been issued on electric vehicle charging [13] and alternative fuels [14]. These mandates result in the publication of relevant European standards (based on parallel international standards). CENELEC will expedite the adoption of international standards (or TS, wherever appropriate) and develop specific EN documents only where no corresponding international documents are in existence.

7.3 Specific distribution network issues

The typical European low-voltage distribution network is 3×400 V + N, giving a single phase + neutral voltage of 230 V. However, 3×230 V networks are widely used in Belgium (particularly in urban areas) and are also found in Norway and Italy. In such systems, single-phase supply is taken between two phases (Fig. 3) [8].

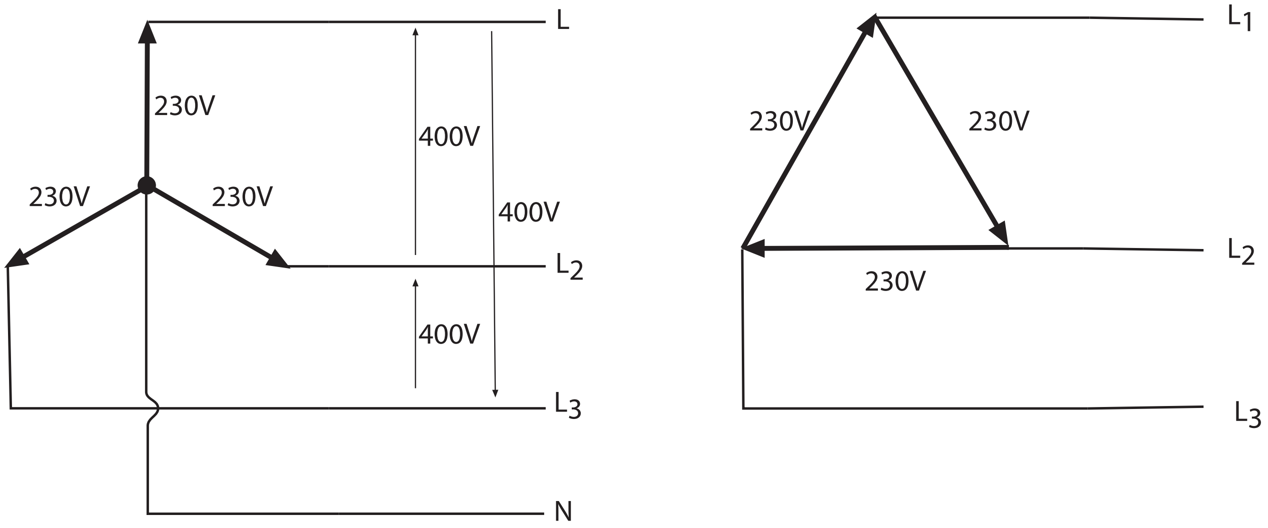


Figure 3: Distribution networks 3×400V (left) and 3×230V (right)

The a.c. charging outlets (Type 2) are provided for 3 × 400 V three phase, but are also deployed with single-phase connection (L1 and N pins), particularly for private charging points, as domestic users often have one phase available only. On a 3 × 230V connection, two phases will then be connected to the L1 and N pins. This configuration works fine with most electric vehicles, but some types of vehicles, being designed for 3×400 V + N in countries where the 3×230V system is unknown, refuse to charge when they do not perceive a neutral wire. This may force EV users having 3×230 V at home to purchase a separation transformer, an unnecessary cost to be avoided. As these 3×230 V installations are perfectly safe and conform to wiring regulations (all Belgian electrical installations have to comply to the AREI regulation [15]), there is no reason for EVs not to charge on such systems.
For three-phase charging from a 3×230 V network however, a transformer will be necessary in any case.

8 Conclusions

The development of performant charging network has to keep pace with the growing deployment of electric vehicles, as to maximize user convenience and flexibility and to do away with range anxiety. 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 to reach the ideal of global standard solutions optimally covering user needs and fulfilling the highest safety requirements;
As with all standardization matters, charging standards incorporate the three main pillars of the house of standardization: safety, compatibility and performance.
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.

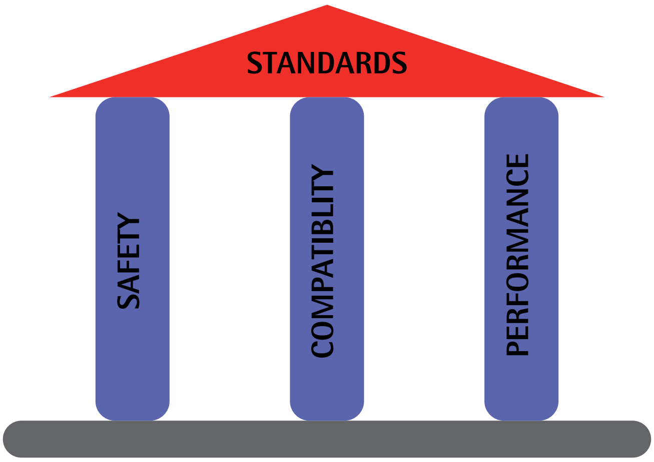


Figure 4: The House of Standardization [16]

References

[1] IEC61851-1/CDV, Electric vehicle conductive charging system – Part 1: General requirements, No. 69/364/CDV, IEC TC69 WG4, 2015.

[2] IEC61851-23, Electric vehicle conductive charging system – Part 23: d.c. electric vehicle charging station, 1st Edition, IEC, 2014.

[3] IEC61851-24, Electric vehicle conductive charging system - digital/data communication of d.c. charging control between off-board d.c. charger and electric vehicle, 1st Edition, IEC, 2014.

[4] IEC62196-1, Plugs, socket-outlet and vehicle couplers – conductive charging of electric vehicles — Part 1: Charging of electric vehicles up to 250 A a.c. and 400 A d.c., 3rd Edition, IEC, 2014.

[5] IEC62196-2, Plugs, socket-outlet and vehicle couplers – conductive charging of electric vehicles — Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories with rated operating voltage up to 250V a.c. single phase and rated current up to 32A, 1st Edition, IEC, 2011.

[6] IEC62196-3, Plugs, socket-outlet and vehicle couplers – conductive charging of electric vehicles — Part 3: Dimensional interchangeability requirements for d.c. and a.c./d.c. pin and tube-type vehicle couplers, 1st Edition, IEC, 2014.

[7] EU, Directive 2014/94/EU of the European parliament and of the council on the deployment of alternative fuels infrastructure, Vol. 57, OJ L307, 2014-10-28, 2014.

[8] B. Rotthier, T. Van Maerhem, P. Blockx, P. Van den Bossche, J. Cappelle, Home charging of electric vehicles in belgium, in: EVS-27, Barcelona, 2013.

[9] IEC62752, In-cable control and protection device for mode 2 charging of electric road vehicles (IC-CPD), 1st Edition, IEC, 2016.

[10] IEC60364-7-722, Low-voltage electrical installations - Part 7-722: Requirements for special installations or locations - Supplies for electric vehicles, 1st Edition, IEC, 2015.

[11] IEC61980-1, ELECTRIC VEHICLE WIRELESS POWER TRANSFER (WPT) SYSTEMS - Part 1: General requirements, 1st Edition, IEC, 2015.

[12] Directive 2014/35/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits (recast)., OJ L 96, 29 March 2014, 2014.

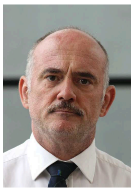
[13] European commission, STANDARDISATION MANDATE M/468 TO CEN, CENELEC AND ETSI CONCERNING THE CHARGING OF ELECTRIC VEHICLES, 2010.

[14] European commission, COMMISSION IMPLEMENTING DECISION of 12.3.2015 on a standardisation request addressed to the European standardisation organisations, in accordance with Regulation (EU) No 1025/2012 of the European Parliament and of the Council, to draft European standards for alternative fuels infrastructure, 2015.

[15] AREI, Algemeen Reglement op de Elektrische Installaties, Kluwer, 2015.

[16] P. Van den Bossche, Matching accessories: Standardization developments in electric vehicle infrastructure, in: EVS-25, 2010.

Authors



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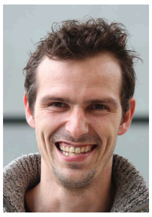

Tom Turcksin graduated as industrial engineer from the Erasmushogeschool Brussel and as aeronautical engineer from the Vrije Universiteit Brussel. He is currently active as researcher within the Vrije Universiteit Brussel’s MOBI team, focusing on battery thermal management and ageing.

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