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Conductive charging of electric vehicles: developments at the low and high end of the power spectrum

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Executive Summary

Whileas charging infrastructure standardization is now well developed for cars, new evolutions are going on for light electric vehicles on one hand and for high power charging on the other hand. In both those areas, new standards and technical specifications are being drafted. The paper focuses on both ends of the power spectrum, highlighting current evolution and analysing problems and opportunities in the standardization process.

1 Introduction

Charging infrastructure standardization is a key element in the development of electric mobility, and thus has been the subject of substantial international standardization work, performed on a global level foremostly by IEC technical committee 69.

This paper will focus on both the low and high end of the charging power spectrum and on the ongoing standardization projects in these two fields.

2 Effective standardization in the middle section

Most standardization work on charging infrastructure has been performed for passenger cars. It must be said that this work has been quite successful, with the general charging concept described in IEC 61851-1 [1], the third edition of which was published in 2017, and accessories according to the IEC62196 series [2, 3, 4].

For AC charging, standard infrastructure is now nearly universally spread. The European directive on alternative fuels infrastructure [5] has mandated Type 2 accessories according to IEC62196-2; these are now nearly universally used on European AC charging stations. Vehicles may have a Type 2 or Type 1 inlet; for their new models on the European market, also non-European manufacturers like Nissan are adopting type 2 inlets.

The situation is a bit more complex for DC charging, where in Europe two systems co-exist: CHAdeMO an CCS, although the latter has been prescribed by the European directive. A third system, using a Type2-style inlet for both AC and DC charging with commutable pins, is used by Tesla in Europe although it has not been covered by international standards yet.

3 The low end: issues with light electric vehicles

3.1 IEC61851-3 series

The so-called ”light electric vehicles” (including two- and three-wheelers) have their particular requirements. Charging of such vehicles often makes use of portable devices and batteries can be easily swappable for indoor charging.

The first main issue of standardization, and the first clause of any standard is of course the scope, in this case defining what is to be understood as ”light” electric vehicles. This is not a straightforward definition as vehicle classification is defined by national regulations and is primarily an administrative matter. There exist international categorization of vehicles by UNECE [6], reflected in the European regulations for type approval of vehicles [7], but national regulations may be divergent, also due to the fact that some ”light electric vehicles” (such as speed-pedelecs or E-assisted transport modes, for which a new TC is being consituded in IEC) may constitute ”new” products where existing regulations do not cater for yet.

The project 61851-3 was set up by IEC TC69 to deal with the standardization of conductive charging for light electric vehicles. Its first draft only mentioned ”light electric vehicles” without precise definition of the term [8].

Substantial discussions arose however within the working group concerning the scope of the documents. It had to be reminded that the first aim of the standards is not to endorse administrative categories for vehicles, but to ensure electrical safety. The main point is not the size or weight of the vehicle, but how protection against electric shock is being provided. In electric vehicles such as cars, the protection is provided through a protective earth conductor as described in IEC61851-1 [1], whileas the ”light” vehicles considered in this document make use of double or reinforced insulation.

To this effect, the title and scope of the documents in the IEC61851-3 series has been revised [9]. These documents are expected to be published as Technical Specifications in a first stage, with DTS drafts circulated in the spring of 2019. The standard IEC61851-3 is divided in the following parts:

1. Electric Vehicles conductive power supply system - Part 3-1: General Requirements for EV supply equipment where protection relies on double or reinforced insulation - AC and DC conductive power supply systems [10]. The aspects covered in this document include:
   - the connection to the vehicle
   - characteristics to be complied with by the vehicle with respect to the AC or DC
   - the specification for required level of electrical safety for the double or reinforced insulation EV supply equipment
   - operators and third party electrical safety
   - requirements for basic communication for safety and process matters if required
   - requirements for bidirectional power transfer DC to DC
   - the connection to installations according to IEC60364-7-722 [11]
   - specific EMC requirements for EV supply systems to the extent not covered by IEC61851-21-2 [12]
2. Electric Vehicles conductive power supply system - Part 3-2: Particular requirements EV supply equipment where protection relies on double or reinforced insulation - Voltage converter unit [13]. This part applies to voltage converter units (such as battery chargers) and is based on IEC60335-2-29 [14], a standard about household battery chargers developed by IECTC61.
3. Electric Vehicles conductive power supply system - Part 3-3: Requirements for Light Electric Vehicles (LEV) battery swap systems [15]. This document follows a separate track from all other parts which art treated in parallel. It applies to battery swap systems for removable RESS/EV where the removable RESS/EV is stored for the purpose of transfer power between the battery swap station and removable RESS/EV. These removable battery systems are intended to be handled by unskilled people. Requirements for bidirectional energy transfer DC to AC are under consideration and are not part of this edition.
4. Electric Vehicles conductive power supply system - Part 3-4: Particular requirements EV supply equipment where protection relies on double or reinforced insulation - General definitions and requirements for CANopen communications [16]. This document describes the use of CAN bus messages for communication purposes between different elements of the system. The CAN bus [17] is very widespread for automotive and other applications. This is to be seen in the framework of energy management systems for control of power transfer between battery systems and voltage converter units, specifying the communication for all devices that may take part in energy management control. Such energy control applications may be implemented in e.g. EVs, robots, offshore parks, isolated farms, etc.

5. Electric Vehicles conductive power supply system - Part 3-5: Particular requirements EV supply equipment where protection relies on double or reinforced insulation - Pre-defined communication parameters and general application objects [18]. This document provides specifications with regard to the pre-defined communication parameters and general application objects.

6. Electric Vehicles conductive power supply system - Part 3-6: Particular requirements for EV supply equipment where protection relies on double or reinforced insulation - Voltage converter and communication [19]. This document specifies application objects for CAN communication, provided by the AC/DC or DC/DC voltage converter unit.

7. Electric vehicles conductive power supply system - Part 3-7: Particular requirements for EV supply equipment where protection relies on double or reinforced insulation Battery system communication [20]. This document specifies application objects for CAN communication, provided by the battery system.

3.2 IEC61851-23-2

Another way to provide protection against electric shock is by using electrical separation, as described in IEC61140 [21]. In this case, exposed conductive parts (such as the vehicle body) can also be foregone as the chargers are fitted with isolation transformers providing protection by electrical separation.
This approach is reflected in the project IEC61851-23-2, which is now going towards DTS stage [22].

This document applies to the DC EV supply equipment for charging electric road vehicles, with a rated supply voltage up to 480V AC or up to 600 V DC with output voltages up to 120 V DC and output currents up to 100 A DC, giving requirements for DC EV supply equipment where the secondary circuit is protected from primary circuit by electrical separation. 114 The aspects covered in this document include:

- the characteristics and operating conditions of the DC EV supply equipment
- the specification of the connection between the DC EV supply equipment and the EV
- the requirements for electrical safety for the DC EV supply equipment

Initially intended to be a complement of IEC61851-23 [23] aimed at systems with smaller energy capacity for ”light” vehicles, this document has now become more self-standing and may receive a new number not in the 61851-23 series.

The fundamental difference in approach as to electrical safety between IEC61851-3 series and 61851-23-2 has given rise to thorough discussions within the committees. It should be noted that there is a certain overlap as to the applications, and proper co-ordination should be provided to avoid conflicting standardization. This different approach is also rooted in cultural differences: whileas IEC61851-3 documents originate from Europe, the IEC61851-23-2 project is of Japanese background. Attitudes towards electrical safety differ, with for example class 0 equipment (without protective conductor, but no double or reinforced insulation) being permitted in Japan.

3.3 Accessories

Specific accessories are proposed for the systems described in IEC61851-3 series in the IEC SC23H Technical Specification IEC62196-4 expected for 2019 [24]. Based on IEC62196-1 [2], this document presents standard sheets for accessories, with a maximum operating voltage up to 120V DC, and a current not exceeding 60 A, where the protection against electric shock is provided by double or rei,fordec insulation, hence without protective earth contact. The accessories are however provided with auxiliary contacts, as well as NFC coils, for communication purposes.

As for the accessories using electrical separation as a means of protection against electric shock as in IEC61851-23-2, the project IEC62196-6 is being prepared. This project is now at CD stage [25].

4 The high end: ultra-high power charging for buses and cars

4.1 Charging for buses

Battery-electric buses offer interesting opportunities for environmentally friendly public transport. The demanding operation of a city bus during all-day operation is often dependent on the availability of opportunity charging en-route, for example at bus line terminals where there is some time available. Using traditional conductive cables with connectors would be cumbersome, for this reason the use of automatic connection systems such as pantographs is considered.

This is the subject of the IEC61851-23-1 project [26]. This is strictly a complement to IEC61851-23, with the organization of the charging being identical to the CCS connector system, with only the automatic connection device replacing the cable and connector. The charger proper is located on the ground and the connection with the pantograph encompasses, apart from the two DC lines, the protective conductor and control pilot.

This approach is to be discerned from the connection of the bus to an unregulated DC supply (e.g. 700V DC for trams) which is also being implemented in some cases but not yet covered by standardization.

Work on this project is advancing well, it will however only be able to reach CDV status once the parent document 61851-23 will have reached this stage for its second edition.

The automatic connection systems themselves are not within the scope of this document, and there is no SC23H project yet. However, CENELEC TC23H has started its project EN50696 ”Contact Interface for Automated Connection Device”, covering specifications concerning the contact interface for charging of electrical vehicles/buses which make use of an automated connection device. This standard describes the requirements for an automated connection device (ACD) in regard of safety, function and testing. This standard describes basic parameter that can be standardized for different ACDs. ACDs following these standardized parameters will have the benefit to be exchangeable, even if they are based on different technologies.
This document is now at committee stage, with no CD circulated yet, and may become IEC project in the future.

The issue is also being treated by CENELEC TC9X WG27, the survey group for current collectors on commercial road vehicles in overhead contact line operation, under the aegis of the railway committee TC69X.

4.2 Charging for cars

High-power charging is being considered for passenger cars too, with power levels considerably higher than the 50kW level typical for the ”fast” charging considered in IEC61851-23 and related documents. Vehicle battery energy is increasing, exceeding 100 kWh in some vehicles, and charge power demand increases too to allow for shorter charging times. Power levels of 150 kW up to 350 kW and more are being proposed now.
The introduction of such high power levels brings some challenges however:

- The batteries must be fit to accept such high charging powers. This is the case for some battery chemistries such as LTO; on the other hand, charging power shall always be considered in relationship to the battery capacity as to judge strain on the battery. For a 100kWh battery, the 50kW of a traditional fast charger is not really ”fast”.
- High power will need either high current or high voltage, with their respective problems:
  - High currents need thick and heavy cables and connectors which would be difficult to handle. Special design features such as cooling systems are advised in order to avoid unmanageable situations. Standardization will have to take into account the expertise of various committees beyond the EV committee IEC TC69 and the accessory committee IEC SC23H, such as IEC TC20 (cables). A special ad-hoc group has been set up to deal with these issues, leading to initiatives which may create new standards in the field.
  - High system voltages are being proposed; the use of voltages which are legal high voltage (over 1000V AC or 1500V DC) may cause administrative problems however in that non-skilled users such as ordinary drivers are not allowed to handle it, even when the accessories are safe and dead when being manipulated
- the electric distribution network must be able to deliver the demanded power, which at peak moments could be expensive and only to be considered within a wider framework of distributed energy storage either in stationary batteries or in vehicle batteries through vehicle-to-grid systems. The

latter are still under consideration in the standards. The implementation of these concepts is one of the main challenges in standardization, necessitating collaboration over committee boundaries, such as the current liaison between TC69 and TC57.

Although the ultra-high-power charging may have useful applications such as motorway service areas for long distance driving, the concept of charging the electric car in a few minutes is reminescent of a ”gasoline station” paradigm which is a marketing argument and not necessary the most efficient and cost-effective way to ensure the energy supply to electric vehicles, where the smooth charge during times where electricity is cheap and readily available offers the best opportunities, on both technical, economical and ecological viewpoint.

5 Conclusions

International standardization continues to play a key role in facilitating safe and interoperable electric vehicle energy supply infrastructures, and this for the whole spectrum of power levels and vehicle types, from bicycle to bus.
Effective collaboration between all committees involved, under the cupola of IEC (with ISO for vehicle-centric issues) once more proves the best way to proceed, overcoming technical issues as well as legal and cultural differences, in order to allow global solutions.

References

[1] IEC61851-1, *Electric vehicle conductive charging system – Part 1: General requirements*, 3rd ed. IEC, 2017.

[2] 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 ed. IEC, 2014.

[3] IEC62196-2, *Plugs, socket-outlet and vehicle couplers – conductive of electri charging c 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*, 2nd ed. IEC, 2016.

[4] 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 ed. IEC, 2014.

[5] European Union, *Directive 2014/94/EU of the European Parliament and of the Council on the deployment of alternative fuels infrastructure*. OJ L307, 2014-10-28, 2014, vol. 57, no. L307.

[6] UNECE, *Consolidated Resolution on the Construction of Vehicles*. UNECE, 2017, no. ECE/TRANS/WP.29/78/Rev.6.

[7] European Union, *REGULATION EU No 168/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the approval and market surveillance of two- or three-wheel vehicles and quadricycles*. OJ L 60/52, 2013-03-02, 2013, vol. 52, no. L60.

[8] IEC61851-3-1/CD, *ELECTRIC VEHICLES CONDUCTIVE POWER SUPPLY SYSTEM – Part 3-1, General Requirements for Light Electric Vehicles AC and DC conductive power supply systems*, 1st ed. IEC TC69 WG10, 2014, no. 69/305/CD.

[9] 69/557/RQ, *Title of standards in the IEC 61851-3 series*. IEC TC69, 02 2018.

[10] IEC61851-3-1/DTS, *Electric Vehicles conductive power supply system - Part 3-1: General Requirements for EV supply equipment where protection relies on double or reinforced insulation - AC and DC conductive power supply systems*, 1st ed. IEC TC69 WG10, 4 2019, no. 69/648/DTS.

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

[12] IEC61851-21-2, *Electric vehicle conductive charging system - Part 21-2: Electric vehicle requirements for conductive connection to an AC/DC supply - EMC requirements for off board electric vehicle charging systems*, 1st ed. IEC TC69, 2018, no. 69/531/FDIS.

[13] IEC61851-3-2/DTS, *Electric Vehicles conductive power supply system - Part 3-2: Particular requirements EV supply equipment where protection relies on double or reinforced insulation - Voltage converter unit*, 1st ed. IEC TC69 WG10, 4 2019, no. 69/649/DTS.

[14] IEC60335-2-29, *Household and similar electrical appliances – -Safety – Part 2-29: Particular requirements for battery chargers*, 3rd ed. IEC, 2016.

[15] IEC61851-3-3/CD, *Electric Vehicles conductive power supply system - Part 3-3: Requirements for Light Electric Vehicles (LEV) battery swap systems*, 1st ed. IEC TC69 WG10, 2018, no. 69/636/CD.

[16] IEC61851-3-4/DTS, *Electric Vehicles conductive power supply system - Part 3-4: Particular requirements EV supply equipment where protection relies on double or reinforced insulation - General definitions and requirements for CANopen communications*, 1st ed. IEC TC69 WG10, 4 2019, no. 69/650/CD.

[17] ISO11898-2, *Road vehicles – Controller area network (CAN) – Part 2: High speed medium access unit*, 1st ed. ISO, 2003.

[18] IEC61851-3-5/DTS, *Electric Vehicles conductive power supply system - Part 3-5: Particular requirements EV supply equipment where protection relies on double or reinforced insulation - Predefined communication parameters and general application objects*, 1st ed. IEC TC69 WG10, 4 2019, no. 69/651/CD.

[19] IEC61851-3-6/DTS, *Electric Vehicles conductive power supply system - Part 3-6: Particular requirements for EV supply equipment where protection relies on double or reinforced insulation - Voltage converter and communication*, 1st ed. IEC TC69 WG10, 4 2019, no. 69/652/CD.

[20] IEC61851-3-7/DTS, *Electric vehicles conductive power supply system - Part 3-7: Particular requirements for EV supply equipment where protection relies on double or reinforced insulation – Battery system communication*, 1st ed. IEC TC69 WG10, 4 2019, no. 69/653/CD.

[21] IEC61140, *Protection against electric shock – Common aspects for installation and equipment*, 3rd ed. IEC, 2001.

[22] IEC61851-23-2CDV, *Electric vehicle conductive charging system – Part 23-2: DC EV supply equipment where protection relies on electrical separation*. IEC TC69, 07 2018, no. 69/609/CDV.

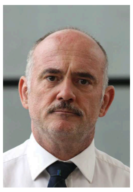
[23] IEC61851-23, *Electric vehicle conductive charging system – Part 23: d.c. electric vehicle charging station*, 1st ed. IEC, 3 2014.

[24] IEC62196-4DTS, *Plugs, socket-outlets, vehicle connectors and vehicles inlet – Conductive charging of electric vehicles – Part 4: Dimensional compatibility and interchangeability requirements for DC pin and contact-tube accessories for class II or class III applications*. IEC SC23H, 3 2017, no. 23H/382/DTS.

[25] IEC62196-6/CD, *Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles – Part 6: Dimensional compatibility requirements for DC pin and contact-tube vehicle couplers for DC EV supply equipment where protection relies on electrical separation*. IEC SC23H, 1 2019, no. 23H/439/CD.

[26] IEC61851-23-1/CD, *Electric vehicle conductive charging system - Part 23-1: DC Charging with an automatic connection system*. IEC TC69 PT61851-23-1, 09 2018, no. 69/623/CD.

Authors



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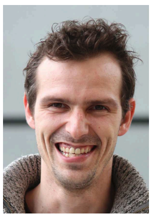

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