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A Tale of Three Plugs: Infrastructure Standardization in Europe

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Abstract

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 operation of the electrically propelled vehicle is dependent on the availability of efficient electric energy storage devices: the traction batteries. To allow the use of cheap and clean electric energy from the grid, recharging infrastructures shall be available to transfer electric energy from the distribution grid to the battery. This transfer can be done either by *conduction* or by *induction*, with the first system being the most widely used.
This paper will present the current evolution in the field of conductive charging infrastructure standardization, giving special interest to ongoing European developments in the field.

Keywords: standardization,charging, conductive charger,infrastructure, European Union

1 General issues

1.1 Global standardization

Standardization, on a global level, is mainly dealt with by two institutions: the *International Electrotechnical Commission* (IEC), founded in 1904, deals with all things electrical, whileas the *International Organization for Standardization* (ISO), founded in 1948, deals with all other technologies. With standardization of the electric road vehicle becoming a key issue, the question arises which standardization body would have the main responsibility for electric vehicle standards. This problem is less straightforward then it looks: the electric vehicle, which introduces electric traction technology in a road vehicle environment, represents in fact a mixed technology, being both a ”road vehicle” and an ”electrical device”.
One can discern a fundamentally different approach taken towards the concept of standardization in the automotive and the electrotechnical world. There is a different ”standardization culture”, the origin of which can be traced back to historical reasons.
For this reason, collaboration between relevant ISO and IEC standardization committees in the field of electric vehicles has not always run very smoothly since the foundation of the respective working groups, ISO TC22 SC21 and IEC TC 69, in the early 1970s. During the years however, there have been considerable discussions between the two groups as to the division of the work, in which there were a number of overlaps and issues for discussion. By the end of the 1990s, a consensus was agreed defining the specific competences of the respective committees, as shown in Table 1.

Table 1: Basic division of work IEC/ISO

ISO	IEC
Work related to the electric vehicle as a whole	Work related to electric components and electric supply infrastructure

1.2 European standardization

Within Europe, CENELEC and CEN operate as the pendants of IEC and ISO. Both have been active in electric vehicle standardization in the 1990s, through their technical committees CENELEC TC69X and CEN TC301. However, much of this work was parallel to the global standardization work, with the European standards created superseded by international standards when these were available (such as prEN50275 vs. IEC61851 and EN1987 vs. ISO6469).
Both committees went dormant around the turn of the century. TC301 however was reactivated as a general CEN technical committee dealing with road vehicles. TC69X was reactivated in 2011 following the activities of the Focus Group, with the aim of expediting the European adoption of IEC TC69 documents.

In June 2010 the DG Enterprise & Industry of the European commission issued a mandate M468 concerning the charging of electric vehicles [1]. The mandate was addressed not only to CEN and CENELEC, but also to the telecommunications standards body ETSI. The standards bodies were requested to develop European standards or to review existing standards in order to:

- Ensure interoperability and connectivity between the electricity supply point and the charger of electric vehicles, including the charger of their removable batteries, so that this charger can be connected and be interoperable in all EU States.
- Ensure interoperability and connectivity between the charger of electric vehicle- if the charger is not on board- and the electric vehicle and its removable battery, so that a charger can be connected, can be interoperable and re-charge all types of electric vehicles and their batteries.
- Appropriately consider any smart-charging issue with respect to the charging of electric vehicles.
- Appropriately consider safety risks and electromagnetic compatibility of the charger of electric vehicles in the field of LVD Directive 2006/95/EC [2] and EMC Directive 2004/108/EC [3].

To respond to the demands of the mandate, CEN and CENELEC constituted the *Focus Group on European Electro-Mobility - standardization for road vehicles and associated infrastructure* as an (informal) joint working group, reporting to the CEN and CENELEC Technical Boards.

The Focus Group considered in the first instance European requirements relating to standardization for road vehicles and associated infrastructure, and assessed ways to address them. The Focus Group is not destined to itself create standards documents nor create regulatory requirements. This remains the competence of the relevant standardization organizations and regulatory authorities.

The Focus Group had a very wide participation, including representatives of the CEN and CENELEC national members often from local industry or Governments - and of all major European associations of stakeholders in the field. Observers fully participating have included representatives of technical standards committees in CEN, CENELEC, ISO and IEC, from some other standards organizations and from the European Commission services.
The final report in response to the commission mandate was presented to CEN and CENELEC technical boards in June 2011 [4].

This report formulated a number of recommendations affecting the development of electric vehicle standardization issues in Europe. It is aimed at the relevant standards committees, also involving other committees that are relevant to the subject such as IEC TC64 (Safety of electrical installations), IEC TC13 (Metering), IEC SC17D (Low-voltage switchgear and controlgear assemblies), IEC SC23H (Plugs and sockets) and IEC TC57 (Smart Grid), as well as the corresponding European technical committees in the framework of CENELEC. For the sake of communication, interaction will also be sought with ETSI.
Also, interaction with regulatory bodies shall be established, on one hand concerning vehicle type approval which are dealt with by UNECE regulations [5], on the other hand with electric wiring regulations which may differ strongly between different countries. Electrical safety is a vital requirement and protection against electric shocks remains the key driver of electric equipment standardization.
With the publication of this final report, the task of the Focus Group is achieved. However, its work will be pursued by the establishment of a CEN-CENELEC Electro-Mobility Co-ordination Group with the aim to support coordination of standardization activities during the critical phase of writing new standards or updating existing standards on Electro-Mobility, and make recommendations accordingly. This group is being constituted in the Spring of 2012.

2 Electric vehicle charging

2.1 Charging modes for conductive charging

The so-called *charging modes* were introduced in the international standard IEC61851-1 [6].

2.1.1 Mode 1 charging

Mode 1 charging refers to the connection of the EV to the a.c. supply network (mains) utilizing standardized socket-outlets (i.e. meeting the requirements of any national or international standard), with currents up to 16A. This corresponds to non-dedicated infrastructures, such as domestic socket-outlets, to which electric vehicles are connected for charging.

These socket-outlets can easily and cheaply deliver the desired power, and due to their availability, Mode 1 charging is the most common option for charging electric vehicles, particularly when existing infrastructures are to be used.

There are however a number of safety concerns to be taken into account. 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) switching off the supply if a leakage current greater than a certain value (e.g. 30mA) is detected.

In most countries, RCDs are now prescribed for all new electric installations. There are however still a lot of older installations without RCD present, and it is often difficult for the EV user to know, when plugging in, the vehicle, whether or not a RCD is present. Whileas some countries leave this responsibility to the user, Mode 1 has therefore been outlawed in a number of countries such as the United States.

Furthermore, some countries like Italy do not allow Mode 1 charging for charging places accessible to the public and limit its use to private premises, out of concern that live standard socket-outlets in public places may be exposed ito the elements, vandalism or unauthorized access.

In countries where the use of Mode 1 charging is allowed, it will remain a preferred mode for private premises (including residential garages as well as corporate parking lots) due to its simplicity and low investment cost. With a proper electrical installation including RCD, Mode 1 allows charging in full safety.

However, the uncertainty faced by the user about the presence of an RCD when plugging in the electric vehicle in an arbitrary standard outlet makes that a potential hazard may be present. For this reason, vehicle manufacturers tend to steer away from Mode 1 charging, preferring Mode 3, with Mode 2 as a transitory solution.

Mode 1 charging is now only considered as the main mode for small vehicles such as scooters and quadricycles. [4]

2.1.2 Mode 2 charging

Mode 2 charging connection of the EV to the a.c. supply network (mains) also makes use of standardized socket-outlets. It provides however additional protection by adding an *in-cable control box* (ICCB) with a control pilot function between the EV and the control box.

The introduction of Mode 2 charging was initially mainly aimed at the United States, as a transitional solution. It is now however receiving some new interest to replace Mode 1 for charging at non-dedicated outlets.

The main disadvantage of Mode 2 is that the control box protects the downstream cable and the vehicle, but not the plug itself, whereas the plug is one of the components more liable to be damaged in use. Furthermore, the use of the ICCB is not elegant and not always very practical, e.g. in public environments.

The CEN-CENELEC Focus Group recommended that occasional charging on private premises should preferably be done using mode 2 to ensure RCD protection. [4].

2.1.3 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 refers to private or public charging stations. The standard IEC61851-1 [6] mandates control pilot protection between equipment permanently connected to the a.c. supply network and the electric vehicle.

For Mode 3 charging, the IEC 61851-1 standard foresees additional protection measures to be provided by the so-called *control pilot*, a device 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 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 controls the current absorbed by the charger, thus allowing dynamic ampacity control (see also 4).

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.

The connection process shall be such that the earth connection is made first and the pilot connection is made last. During deconnection,

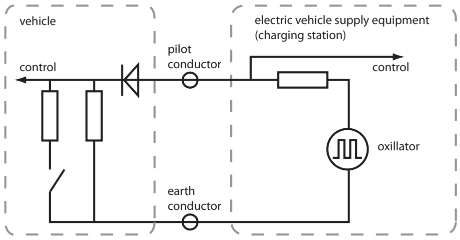

Figure 1: Control pilot conductor scheme

the pilot connection shall be broken first and the earth connection shall be broken last. This sequence also ensures that the current is interrupted at the contactor and not at the power contact pins of the plug, thus eliminating arcing and prolonging the service life of the accessories.

The use of a control pilot conductor in charging equipment was first proposed around 1990 for charging stations for electric boats deployed in the Norfolk Broads in England [7].
The use of a control pilot function with fourth wire is also included in the SAE standard J1772 [8].

The use of a dedicated conductor for the control pilot necessitates an extra conductor and thus the use of special cables and accessories.
The new version of the standard 61851-1 [6] has introduced the concept of *control pilot function*, mandatory for Mode 3 charging, which has to perform the same functions as the control pilot conductor, but which can be realized by other means than the extra pilot conductor. The use of a physical control pilot conductor remains an option of course.
Alternative means to implement control pilot functionality include various wireless data transfer systems as well as power line communication. An interesting implementation of the latter has been developed by Electricité de France [9], is described in an informative annex to 61851-1.
It makes use of a control pilot signal as a common-mode signal between the phase wires and the earth conductor, using a 110kHz carrier frequency. Unfortunately, this system has not been adopted yet by vehicle manufacturers.

The inherent safety features, as well as the potential for smart grid integration, make Mode 3 a preferred solution, it was thus recommended by the Focus Group for public charging stations as well as for home charging using dedicated outlet. [4].

2.1.4 Mode 4 charging

Mode 4 charging is defined as the indirect connection of the EV to the a.c. supply network (mains) utilizing an off-board charger where the control pilot conductor extends to equipment permanently connected to the a.c. supply.
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 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.

2.2 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 interference either in the form of radiated electromagnetic waves or as conducted interference on the interconnecting cables. EMC is defined as the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

EMC is heavily regulated, on one hand by the EMC directive 2004/108/EC [3] which pertains to electric and electronic equipment, and on the other hand by the vehicle EMC directive 2004/104/EC [10] which pertains to road vehicles.
Furthermore there are numerous international standards published by IEC, ISO and CISPR dealing with the matter.

The current set of standards covers most of the EMC needs for low frequency phenomena, except in the frequency range between 2 kHz and 150 kHz, a frequency band which contains the typical operating frequencies of power electronic converters as used in electric vehicle traction systems and battery chargers. It will thus be necessary that this frequency range is addressed by standardization as soon as possible.

The low frequency range below 2 kHz is mostly relevant for conductive emissions (power quality and harmonics), for which limits are give by international standards such as IEC61000-3-2 [11] and 61000-3-12 [12].

2.3 Regulatory issues of charging

The difference in national electric regulations and wiring codes constitutes a major challenge for the specification of a pan-European charging system.
Some nations require shutters for socket-outlets in domestic environments, while others do not.
Furthermore, the extension of the scope of the Low Voltage directive [2] has to be defined (Fig. 2). Domestic socket-outlets are not subject to LVD, whileas industrial ones (60309-2) do, this type of plug being harmonized. Dedicated charging equipment will be clearly within the scope of the LVD. The vehicle does not, the applicability of LVD on the vehicle inlet (which is coupled with a connector according to the same standard) is still a matter of discussion however.

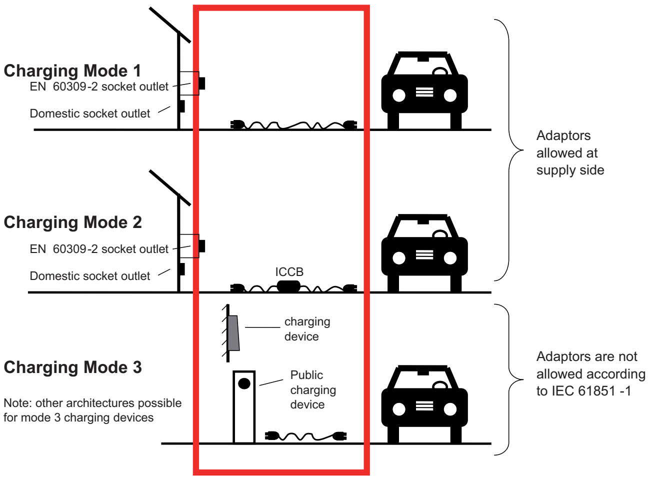

Figure 2: Scope of Low Voltage directive [4]

3 Accessories for charging

3.1 Connection cases

The connection of the cable between the vehicle and the charging outlet can be carried out in three ways as defined in IEC61851-1 [6]:

- Case ”A”: where the cable and plug are permanently attached to the vehicle. This case is generally found only in very light vehicles.

- Case ”B”: where the cable assembly is detachable, and connected to the vehicle with a connector. This is the most common case for normal and semi-fast charging.

- Case ”C”: where the cable and vehicle connector are permanently attached to the supply equipment. This arrangement is typically used for fast charging (Mode 4), so that drivers do not have to carry heavy cables around. Public charging stations using this case are however at a higher risk of copper theft .

3.2 Connection to the a.c. network: plug and socket-outlet

Choosing the right plug presents a first choice point between accessories. There are in fact the following possibilities:

1. Standard domestic plugs For Mode 1 and Mode 2 charging, (also for Mode 3 charging with power-line communication), standard plugs and sockets can be used encompassing only phase, neutral, and earth contacts. In most areas, this will usually be the standard domestic plugs as described in various national standards, and typically rated 10 to 16A [13] (Fig. 3).

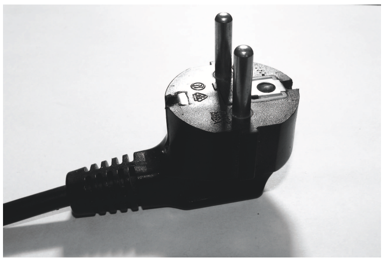

Figure 3: Domestic plug

One has to recognize however that these domestic plugs, particularly the low-cost versions mostly used on consumer grade equipment, are not really suited for the heavy-duty operation of electric vehicle charging, characterized by

- long time operation at near rated current
- frequent operation, including disconnection under rated load
- exposure to outdoor conditions.

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).

2. Standard industrial plugs A better alternative is to use industrial plugs and sockets as defined by the international standard IEC60309-2 [14]. 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 camping sites, marinas, etc., where they function in an operation mode comparable to an electric vehicle charging station. Both plugs/sockets and connector/inlets are available in the IEC60309-2 family. The relatively high insertion force, particularly for higher current versions, has been cited as an issue affecting user-friendliness for electric vehicle deployment. The 16A version would be however a good contender for daily standard charging (Fig 4)

Figure 4: IEC 60309-2 plug (230V, 16A)

These accessories are widely spread on the market and are relatively inexpensive, making them the preferable solution for Mode 1 or Mode 2 charging. The Focus Group [4] proposed them as interim solution pending development of dedicated accessories.

3. Dedicated EV accessories 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 [15] gives general functional requirements; it integrates general requirements from the industrial plug standard IEC60309-1 [16] with the electric vehicle requirements of IEC61851-1 [6].

   Physical dimensions are treated in part 2 [17]. It does present standard sheets for three types of plugs and socket-outlets:

   (a) Type 1
   The Type 1 single phase coupler is rated for 250V and 32A (30A in the United States and Japan). It is fitted with two extra contacts: one for the control pilot (CP) and one for an auxiliary coupler contact (CS) which can be used to indicate the presence of the connector to the vehicle and to signal the correct insertion of the vehicle connector into the vehicle inlet. With a diameter of 44mm, this connector is made in a compact way. This solution reflects the SAE-J1772 standard [8] and is intended as vehicle-side connector for Case ”C” configurations.

   The automobile industry is presently considering mounting both Type 1 and Type 2 inlets on cars and light trucks.

Figure 5: Type1 connector and inlet

   (b) Type 2
   European car manufacturers and utilities however, recognizing the potential benefits of three phase charging and the availability of three phase supply in most European countries expressed the desire for three-phase accessories.
   Type 2 is a three-phase plug rated for currents up to 63A, and has two auxiliary contacts. It is illustrated in Fig. 6 and based on a realisation by the German company Mennekes.

Figure 6: Type2 plug and socket-outlet

   (c) Type 3 Type 3 is also a three-phase type, it is illustrated in Fig. 7 and based on a design by Italian company SCAME further adopted by the ”EV Plug Alliance”. Its design is derived from a single phase plug adopted as national standard in Italy [18] where it is in widespread use particularly for light electric vehicles such as two-wheelers.
   One main difference between Type 2 and Type 3 accessories is the presence of ”shutters” on the latter, providing IPXXD protection.

Figure 7: Type3 plug and socket-outlet

The CEN-CENELEC Focus Group recommended to define one unique footprint for the a.c. plug and socket outlet, encompassing five power contacts (three phases, neutral, earth) and two auxiliary contacts to allow Mode 3 charging. Both Type 2 and Type 3 fit this definition, the final choice between both types should be made rapidly. At this moment, Type 2 can be considered the most popular type in Europe, with Type 3 holding its bases of France and Italy.

3.3 Connectors for d.c. charging

Accessories for d.c. charging will be treated in IEC62196-3. This will only pertain to connectors and vehicle inlets, as d.c. charging stations will typically use a Case C connection.

Solutions considered include the d.c. connector proposed by the CHAdeMO association (Fig. 8).

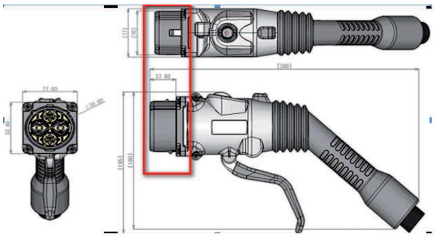

Figure 8: CHAdeMO connector

Furthermore, solutions are proposed encompassing both a.c. and d.c. connections in one unit, the so-called ”combo” connectors (Fig. 9).

Figure 9: Combo connector example

The distinct parts of IEC62196-2 which are being prepared will likely have the character of ”catalogue standards”, presenting standard sheets for various solutions without however making a distinct choice for one particular solution.

4 Communication issues

4.1 Low-level communication: safety and ampacity

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 at all.
Mode 3 introduces communication through the control pilot function. The principle is defined in IEC61851 [6].
In its most basic way of operation, the control pilot only fulfills its essential safety function. The signal can be just a current sent through the control pilot loop to ensure the vehicle is properly connected and the earth connection is sound.
More functionality can be added by using a pulse-width modulation (PWM) signal in the control pilot circuit. The PWM signal can convey information through the variation of its duty cycle.
This feature presents several operational benefits:

- the charger can adjust itself to the maximum allowable current that can be delivered by various charging points, e.g. a standard value of 16A, reduced value of 10A, higher value of 32A for semi-fast charging points.
- 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.

Off-board chargers used in Mode 4, 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 will be covered by part 24 of 61851 [19] now being drafted. This standard will define the messages of digital/data communication to be used during charging control between off-board d.c. charging system and electric road vehicle. It states basic specifications of the communication circuit, which is based on ”Controller Area Network” principles. The document focuses on the upper two layers of the OSI concept [20] , the lower two layers being described in the CAN standard ISO11898 [21, 22].
Annexes to IEC61851-24 will describe several practical protocols reflecting the solutions described in the annexes IEC61851-23 [23], among which the ”CHAdeMO” concept.

4.2 High-level communication: ISO/IEC 15518

The development of new concepts such as ”smart grid” or ”vehicle to grid” has created the need for an appropriate communication protocol for electric vehicle charging beyond the mere safety functions of the control pilot, in order to provide functionalities such as:

- vehicle identification and billing, allowing payment for charging at public charging stations, but also
- individual billing of used energy to the user’s account when the vehicle is charged at any outlet connected to a smart meter outside of the vehicle’s common operating area (roaming)
- charge cost optimization by choosing the most appropriate time window where electricity rates are the lowest
- grid load optimization by controlling charger ampacity in function of grid demand
- peak-shaving functionality by using electric vehicles connected to the grid as a spinning reserve (vehicle-to-grid)
- appropriate billing and user compensation functions for vehicle-to-grid operation

The development of such a communication protocol involves several actors, including both vehicle manufacturers, utilities and various intermediate parties.
The local or remote communication system may have the function of a ”clearinghouse” for the authentication, collecting and consolidation

of grid and billing parameters from the actors as well as transmitting charging process information to the respective actors. Not all such functions are necessarily required for the basic charging functions, and some may be performed locally or remotely. The system can thus become rather complex, and several issues are still to be resolved.

Due to the complex and multidisciplinary nature of the subject, its standardization of this issue is being addressed by a joint working group uniting ISO TC22 SC3 (electric equipment on road vehicles, including onboard communication systems), and IEC TC69 (electric road vehicles), which is drafting a family of standards called ISO/IEC 15118, to describe the communication, in terms of data format and message content, between the electric vehicle and the electric vehicle supply equipment (charging post), as well as message content and data structure to enable billing communication and grid management. Provisions for additional communication aspects (like vehicle charge status information and configuration) are being considered to allow for interoperability of all vehicles with all charging stations.

The basic document of the ISO/IEC 15118 family cases is part 1 ”General information and use-case definition” [24]. ISO/IEC 15118-1 provides a general overview and a common understanding of aspects influencing the charge process, payment and load levelling. It specifies furthermore the initial start-up process and security issues for charging.
Part 2 of ISO/IEC 15118 [25], is called ”Technical protocol description and Open Systems Interconnections (OSI) layer requirements”. This document focuses on the top two layers of the OSI: the physical layer and data link layer, for the communication between vehicle and EVSE.
Part 3 [26] describes the physical and data link layer requirements. This document is at an earlier development stage, now at working draft level [27].

4.3 Use cases and business cases

All envisageable charging processes have to be contextualized in so-called ”use cases” in order to define communication needs. To this effect, the charging process is separated into eight functional groups where elementary use cases can be defined:

- begin of charging process
- communication setup
- identification
- authorization
- target setting and charge scheduling
- charge controlling and re-scheduling
- value added services
- end of charging process

Each use case will be constituted of a combination of elementary use cases, which can be used to construct specific charging scenarios.
These scenarios allow functionalities to be implemented with increased complexity; the increase of user convenience necessitates an extension of data structures to be exchanged.

For each use case, different scenarios are to be defined, relating to the desired control of charging by the grid operator, to the used billing scheme and to the communication system for the user. Several systems are now under consideration and/or used in experimental fleets:

- use of a RFID tag
- communication over the control pilot conductor
- communication (at low or high data rate) through power line communication
- communication with the vehicle’s Can-Bus system
- wireless communication through Bluetooth or ZigBee devices
- communication via mobile phone

The practice of charging of electric vehicles at public charging stations also raises the problem of billing the user for the energy consumed. Payment systems can make use of coins (vulnerable to vandalism), credit cards (creating the necessity of communication systems and involving transaction costs) or dedicated access devices (cards or RFID).

As the value of the electricity typically charged in one opportunity charging session is quite low compared to the parking cost in city centre environment, one can consider to charge the user according to time rather than to energy used, which dispenses the need for (more expensive) electricity counters. Some legal issues have also be considered here, as in some countries the sale of electricity as such is heavily regulated.

The new developments in communication will allow a more sophisticated approach of this issue, with user identification and communication using wireless devices or mobile phones, differential tarification according to time of the day and grid load, as well as compensation for energy returned to the grid. Furthermore, vehicles being charged at varying locations in a ”smart grid” environment will charge the user in a transparent ”roaming” way: wherever the user charges his vehicle, it will be charged on his own bill.

It is clear that considerable standardization work remains to be performed in this field. The drafting of ISO/IEC 15118 will form a good base for a generally applicable family of standards.

To be a true global solution however, there should not be reliance on proprietary protocols allowing global use by all concerned parties. Furthermore, a number of proposed business cases are extremely complex and may raise serious concerns on issues like user freedom of operation and user privacy.

5 Conclusions

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

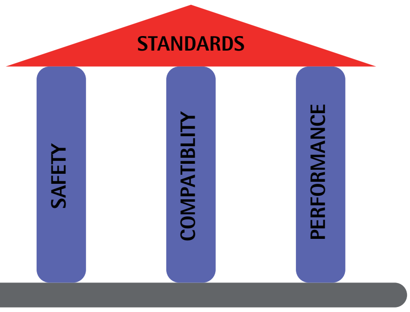

Figure 10: The House of Standardization [28]

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.
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.

Intensive work is now being performed by international standardization committees in order to realize unified solutions which will be a key factor in allowing the deployment of electrically propelled vehicles on a global level, highlighting the technical and societal relevance of standardization.

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References

[1] European commission, Standardisation mandate m/468 to cen, cenelec and etsi concerning the charging of electric vehicles (29 6 2010).

[2] Directive 2006/95/ec of the european parliament and of the council on the harmonisation of the laws of member states relating to electrical equipment designed for use within certain voltage limits, EU OJ L 374, 27.12.2006.

[3] Directive 2004/108/ec of the european parliament and of the council on the approximation of the laws of the member states relating to electromagnetic compatibility and repealing directive 89/336/eec, EU OJ L 390, 31.12.2004.

[4] CEN-CENELEC Focus Group on European Electro-Mobility, Final Report to CEN and CENELEC Technical Boards in response to Commission Mandate M/468 concerning the charging of electric vehicles, CEN-CENELEC, 2011.

[5] UNECE-R100, UNIFORM PROVISIONS CONCERNING THE APPROVAL OF VEHICLES WITH REGARD TO SPECIFIC REQUIREMENTS FOR THE ELECTRIC POWER TRAIN, United Nations Economic Commission for Europe, 2009.

[6] IEC61851-1, Electric vehicle conductive charging system – Part 1: General requirements, 2nd Edition, IEC, 2010.

[7] Benning Ltd., Safe power for electric boats, brochure (1990).

[8] SAE J1772, Electric Vehicle Conductive Charge Coupler, SAE, 2001.

[9] C. Bleijs, Low-cost charging systems with full communication capability, in: EVS-24, Stavanger, 2009.

[10] Directive 2004/104/ec of 14 october 2004 adapting to technical progress council directive 72/245/eec relating to the radio interference (electromagnetic compatibility) of vehicles and amending directive 70/156/eec on the approximation of the laws of the member states relating to the type-approval of motor vehicles and their trailers, EU OJ L337, 13.11.2004.

[11] IEC61000-3-2, Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current 16 A per phase), 3rd Edition, IEC, 2005.

[12] IEC61000-3-12, Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current ¿16 A and 75 A per phase, 2nd Edition, IEC, 2011.

[13] IEC/TR60083, Plugs and socket-outlets for domestic and similar general use standardized in member countries of IEC, 6th Edition, IEC, 2009.

[14] IEC60309-2, Plugs, socket-outlets and plugs for industrial purposes — Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories, 4th Edition, IEC, 2005.

[15] 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., 2nd Edition, IEC, 2010.

[16] IEC60309-1, Plugs, socket-outlets and plugs for industrial purposes — Part 1: General requirements, IEC, 2005.

[17] IEC62196-2/CDV, 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 SC23H, 2010.

[18] CEI-69-6, Foglio di unificazione di prese a spina per la connessione alla rete elettrica di veicoli elettrici stradali, CEI - Italian Electrotechnical Committee, 2001.

[19] IEC61851-24/WD, Electric vehicle conductive charging system - digital/data communication of d.c. charging control between off-board d.c. charger and electric vehicle, IEC TC69 PT61851-24, 2011.

[20] ISO/IEC7498-1, Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model, ISO/IEC, 1994.

[21] ISO11898-1, Road vehicles – Controller area network (CAN) – Part 1: Data link layer and physical signalling, 1st Edition, ISO, 2003.

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

[23] IEC61851-24/CD, Electric vehicle conductive charging system – Part 23: d.c. electric vehicle charging station, 1st Edition, IEC TC69 PT61851-23, 2011.

[24] ISO/IEC15118-1/CD, Road vehicles — Vehicle to grid communication interface — Part 1: General information and use-case definition, 1st Edition, ISO/IEC, 2010.

[25] ISO/IEC15118-2/CD, Road vehicles — Vehicle-to-Grid Communication Interface — Part 2: Technical protocol description and Open Systems Interconnections (OSI) layer requirements, 1st Edition, ISO/IEC, 2011.

[26] ISO/IEC15118-3/CD, Road Vehicles — Vehicle to grid communication interface — Part 3: Physical layer and Data Link layer requirements, ISO/IEC, 2011.

[27] ISO/IEC15118-3/CD, Road Vehicles — Vehicle to grid communication interface — Part 3: Physical layer and Data Link layer requirements, ISO/IEC, 2011.

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

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