Electric Propulsion Vehicles Standardization: Where Are We?

Paulo G. Pereirinha[1,2,3], João P. Trovão[4,1,2,3], Victor Santos[1,2]

[1]IPC-ISEC, Polytechnic Institute of Coimbra, R. Pedro Nunes, P-3030-199 Coimbra (Portugal)
phone:+351 239 790 200, fax:+351 239 790 201, e-mail: ppereiri@isec.pt, vsantos@isec.pt

[2]Institute for Systems and Computers Engineering at Coimbra, INESC-Coimbra, (Portugal)

[3]APVE, Portuguese Electric Vehicle Association, Apartado 7586 – 2610-999 Amadora (Portugal)

[4]DECE, Université de Sherbrooke, Sherbrooke, QC, J1K 2R1, Canada
Joao.Trovao@USherbrooke.ca

Abstract. Electric propelled vehicles, EVs, and Hybrid Electric Vehicles, HEVs, are fundamental for sustainable mobility.
Standardization plays a key role in ensuring safety, components interoperability, generalised recharge possibility, and, in a near future, the possibility of using the EVs as controllable loads with energy storage that can be returned to the grid, in accordance with the demand side management and vehicle-to-grid concepts (DSM and V2G). This paper explains on a compact form the standardization framework in the field of electric vehicles and hybrid electric vehicles, and the most important standardization activities going on (conductive charging systems, wireless power transfer, electric double-layer capacitors for HEV, conductive power supply system for Light EVs, EVs battery swap systems, V2G communication interface, safety and test specifications for lithium-ion traction battery packs and systems, among others). It gives the references that allow engineers working in the electric vehicles area, including its components and interaction with the grid, to seek for the actualized state of the relevant standards at each moment. These two aspects are fundamental to be able to deal with the very high number of standards relevant for EVs and related activities that are in constant update, from different standardization entities.

Key words

Electric vehicles, hybrid electric vehicles, plug-in hybrid electric vehicles, standardization, charging systems.

1. Introduction

Electric Vehicles, EVs, and Hybrid Electric Vehicles, HEV, especially with plug-in capability, PHEV, are fundamental for sustainable mobility [1]-[5]. Although its market share is still quite small, recent studies point that electric vehicles can account for 35 % of global new car sales by 2040 [6]. However, there are still many aspects that can be significantly improved. In addition to research and development, standardization plays a key role in ensuring safety, equipment/components interoperability, and recharge possibility at all or at most of charging stations, etc., and, in a near future, also the possibility of using the electric vehicle as a controllable load and even energy storage that can be returned to the grid, in accordance with the demand side management and vehicle-to-grid concepts (DSM and V2G). Indeed, there has been a so intense activity on the electric vehicles standardization area in the last years that the data presented by the authors in 2011 in [7] needs to be updated.
The main objective of the present paper is to explain, on a compact form, the standardization framework in the field of electric vehicles and hybrid electric vehicles, and the most important standardization activities going on. A secondary objective is to give the references that allow engineers working in the electric vehicles area, including its components and interaction with the grid, to seek for the actualized state of the relevant standards at each moment. These both objectives are fundamental to be able to deal with the very high number of standards, from different standardization entities, relevant for EVs and related activities.

2. Electric Vehicle Global Standardization Framework

As presented in [7], at global level, standardization is mainly under the competence of two institutions: the International Electrotechnical Commission (IEC) [8], founded on 1906, and the International Organization for Standardization (ISO) [9], founded on 1946. In May 2016, IEC had 100 Technical Committees (TC) and 77 Subcommittees (SC) and ISO had 241 TCs (with hundreds of SCs).
At European and National level there are also some relevant standardization organizations, dealing with EVs and HEVs namely:

- CEN, the European Commission for Standardization, where TC 301 – Road Vehicles, is responsible for electric road vehicles.
- CENELEC, the European Committee for Electrotechnical Standardization, TC 69X – Electrical systems for electric road vehicles.
- In the U.S., the Society of Automotive Engineers (SAE).
- In Japan, the Japanese Electric Vehicle Association (JEVA).
- In Portugal, the Portuguese Electric Vehicle Association, APVE, is the "sector standardization

organism" for electric road vehicles. It has two TCs: CTE 69 – *Electric Systems for Electric Road Vehicles*, and CT146 – *Electric Road Vehicles*.

Concerning ISO and IEC, it should be pointed out that an Electric Vehicle is a Road Vehicle, so under the responsibility of ISO/TC22 – Road Vehicles (in particular of ISO TC22/SC21 – *Electrically propelled road vehicles*), but also an "electrical equipment", whose responsibility is of IEC, namely IEC TC69 – *Electric road vehicles and electric industrial trucks*. To avoid overlapping and conflicts between ISO and IEC technical committees, there was a consensus agreement in 1996, basically stating that ISO technical committees deal with the work related to the electric vehicle as a whole and IEC technical committees deal with the work related to electric components and electric supply infrastructure.

To improve and clarify this agreement and to define joint projects and activities an *ISO/IEC Agreement Concerning Standardization of Electrotechnology for Road Vehicles and the Cooperation Between ISO/TC 22 "Road Vehicles" and IEC Technical Committees* was signed in March 2011 [10]. It is valid for all types of road vehicles and their equipment (such as mopeds, motorcycles, motor vehicles, trailers, semi-trailers, light trailers, combination vehicles, and articulated vehicles) and involves five SCs/WGs of ISO TC 22 and 41 TCs & SCs of IEC. The joint standardization activity, IEC/ISO on-going projects by 2010, is presented in Table I.

As can be seen from this table, most of those projects involved at least IEC TC 69, ISO TC 22/SC 21 or ISO/TC 22/SC 3 **(***Electrical and Electronic Equipment*).

It should be pointed out that in 2014, the structure of ISO/TC 22 changed and several new SCs were created (SC 31 to SC41), replacing the previous ones, like the SC3 and SC 8 in Table I. Also in March 2015, ISO TC22/SC21 was closed and its activities transferred to the new ISO/TC 22/SC 37 - *Electrically Propelled Vehicles*, with an adjusted scope of dealing with "Specific aspects of electrically propelled road vehicles, electric propulsion systems, related components and their vehicle integration" [11].

Some of the standards projects' in Table I were meanwhile published but are already starting a revision process, as ISO 15118, cf. Table VI and Table VII).

To overcome the issues raised by different procedures of each organization, ISO/IEC Directives were established to "standardize" common standardization activities [12] [13]. The project stages and associated documents as to be used by both organizations and joint working groups, are shown in Table II.

As of May 2016, IEC TC 69, had 27 *Permanent Member* and 14 *Observer Member* countries, 16 internal liaisons with other IEC TCs and SCs, and liaisons with 6 ISO TCs and SCs: ISO/TC 22, TC 110/SC 2, TC 110, TC22/SC37, TC 22/SC31 and TC 22/SC 38.

TABLE I. - IEC/ISO On-Going Projects [10]

Electrotechnology/ Project	IEC TC/SC	ISO TC/SC
Starter batteries	**TC 21**	TC 22
Secondary lithium cells • IEC 62660-1 Ed 1.0 • IEC 62660-2 Ed. 1.0	**TC 21/SC 21A/TC 69**	TC 22/ SC 21
Lithium batteries – battery pack and system level • ISO 12405-1 Ed. 1.0 • ISO 12405-2 Ed. 1.0	TC 21/SC 21A/TC 69	**TC 22/SC 21**
EV Charging System • IEC 61851 series	**TC 69**	TC 22/SC 21
Vehicle to grid communication interface (JWG V2G CI) • ISO 15118	TC 69	**TC 22/SC 3**
Plugs and Socket-outlets • IEC 62196 series	**SC 23H**	TC 22/SC 3
Lamps, lamp holders and caps	**SC 34A/SC 34B**	TC 22/SC 8
Radio interferences (>= 9 KHz) caused by road vehicle electrical systems	**CISPR D**	TC 22/SC3
EMC emissions on low frequency (<9 kHz) disturbances and basic EMC immunity standards for the whole frequency range	**SC 77A**	TC 22/SC3
EMC immunity for EV charging systems	**TC 69**	TC 22/SC3
EMC immunity for vehicle and its equipment	TC 77	**TC 22/SC3**

Organization in bold has the administrative lead

TABLE II. - Project Stages and Documents for ISO/IEC [12]

Project stage	Associated document	
	Name	Abbreviation
Preliminary stage	Preliminary work item	PWI
Proposal stage	New work item proposal[1)]	NP
Preparatory stage	Working draft(s) [1)]	WD
Committee stage	Committee draft(s) [1)]	CD
Enquiry stage	Enquiry draft [2)]	ISO/DIS — IEC/CDV
Approval stage	final draft International Standard [3)]	FDIS
Publication stage	International Standard	ISO, IEC or ISO/IEC

1) *These stages may be omitted, as described in Annex F of [12]*
2) *Draft International Standard in ISO, committee draft for vote in IEC.*
3) *May be omitted (see 2.6.4 of [12]).*

3. Most Important Standardization Activities in Electric Vehicles

As stated before, ISO TC22/SC37 (former SC21) and IEC TC69 are the most relevant committees regarding EVs standardization. There has been a very intense activity on this area in the last years, as can be seen from the comparison of the following tables and those in [7]. The Standards Published by ISO TC22/SC37 are presented in Table III and those under development are shown in Table IV. The abbreviations and codes meaning are shown in Table V. Comparing Table III and IV, it can be seen that, for example, the first 3 ISO 6469 parts, just published on 2009 and 2011, are already at different stages of a revision process.

TABLE III. – Standards Published by ISO TC22/SC37 (former SC21) and status codes by May 2016 [14]

Standard and/or project	**Code**
ISO 6469-1:2009 - Electrically propelled road vehicles -- Safety specifications -- Part 1: On-board rechargeable energy storage system (RESS)	90.92
ISO 6469-2:2009 - Electrically propelled road vehicles -- Safety specifications -- Part 2: Vehicle operational safety means and protection against failures	90.92
ISO 6469-3:2011 - Electrically propelled road vehicles -- Safety specifications -- Part 3: Protection of persons against electric shock	90.92
ISO 6469-4:2015 - Electrically propelled road vehicles -- Safety specifications -- Part 4: Post crash electrical safety	60.60
ISO/TR 8713:2012 - Electrically propelled road vehicles – Vocabulary	90.92
ISO 8714:2002 - Electric road vehicles -- Reference energy consumption and range -- Test procedures for passenger cars and light commercial vehicles	90.93
ISO 8715:2001 - Electric road vehicles -- Road operating characteristics	90.93
ISO/TR 11954:2008 - Fuel cell road vehicles -- Maximum speed measurement	60.60
ISO/TR 11955:2008 - Hybrid-electric road vehicles -- Guidelines for charge balance measurement	60.60
ISO 12405-1:2011 - Electrically propelled road vehicles -- Test specification for lithium-ion traction battery packs and systems -- Part 1: High-power applications	60.60
ISO 12405-2:2012 - Electrically propelled road vehicles -- Test specification for lithium-ion traction battery packs and systems -- Part 2: High-energy applications	60.60
ISO 12405-3:2014 - Electrically propelled road vehicles -- Test specification for lithium-ion traction battery packs and systems -- Part 3: Safety performance requirements	90.92
ISO/PAS 16898:2012 - Electrically propelled road vehicles -- Dimensions and designation of secondary lithium-ion cells	90.93
ISO 17409:2015 - Electrically propelled road vehicles -- Connection to an external electric power supply -- Safety requirements	60.60
ISO/PAS 19295:2016 - Electrically propelled road vehicles -- Specification of voltage sub-classes for voltage class B	60.60
ISO 23273:2013 - Fuel cell road vehicles -- Safety specifications -- Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen	60.60
ISO 23274-1:2013 - Hybrid-electric road vehicles -- Exhaust emissions and fuel consumption measurements -- Part 1: Non-externally chargeable vehicles	60.60
ISO 23274-2:2012 - Hybrid-electric road vehicles -- Exhaust emissions and fuel consumption measurements -- Part 2: Externally chargeable vehicles	60.60

TABLE IV. – Standards under Development by ISO/TC 22/SC 37 and status codes by May 2016 [14]

Standard and/or project	**Code**
ISO/NP 6469-1 - Electrically propelled road vehicles -- Safety specifications -- Part 1: On-board rechargeable energy storage system (RESS)	10.99
ISO/CD 6469-2 - Electrically propelled road vehicles -- Safety specifications element -- Part 2: Vehicle operational safety	30.20
ISO/NP 6469-3 - Electrically propelled road vehicles -- Safety specifications -- Part 3: Protection of persons against electric shock	10.99
ISO/NP TR 8713 - Electrically propelled road vehicles – Vocabulary	10.99
ISO/NP 12405-3 - Electrically propelled road vehicles -- Test specification for lithium-ion traction battery packs and systems -- Part 3: Safety performance requirements	10.99
ISO/CD 12405-4 - Electrically propelled road vehicles --Test specification for lithium-ion traction battery packs and systems -- Part 4: Performance testing	30.20
ISO/FDIS 18300 - Electrically propelled vehicles -- Test specifications for lithium-ion battery systems combined with lead acid battery or capacitor	50.00
ISO/AWI PAS 19363 - Electrically propelled road vehicles -- Magnetic field wireless power transfer -- Safety and interoperability requirements	20.00
ISO/AWI 20762 - Electrically propelled road vehicles -- Determination of power for propulsion of hybrid electric vehicle	20.00
ISO/AWI 21498 - Electrically propelled road vehicles -- Electrical tests for voltage class B components	20.00
IEC/FDIS 62752 - In-Cable Control and Protection Device for mode 2 charging of electric road vehicles (IC-CPD)	50.60

TABLE V. – International Harmonized Stage Codes Used by ISO (www.iso.org/iso/stage_codes.pdf)

STAGE	**SUBSTAGE**						
				90 - Decision			
	00 -Registration	**20 - Start of main action**	**60 - Completion of main action**	**92 - Repeat an earlier phase**	**93 - Repeat current phase**	**98 -Abandon**	**99 - Proceed**
00 Preliminary stage	**00.00** - Proposal for new project received	**00.20** - Proposal for new project under review	**00.60** - Close of review			**00.98** - Proposal for new project abandoned	**00.99** - Approval to ballot proposal for new project
10 Proposal stage	**10.00** - Proposal for new project registered	**10.20** - New project ballot initiated	**10.60** - Close of voting	**10.92** - Proposal returned to submitter for further definition		**10.98** - New project rejected	**10.99** - Approval to New project approved
20 Preparatory stage	**20.00** New project registered in TC/SC work programme	**20.20**Working draft (WD) study initiated	**20.60** - Close of comment period			**20.98** - Project deleted	**20.99** - WD approved for registration as CD
30 Committee stage	**30.00** - Committee draft (CD) registered	**30.20** - CD study/ballot initiated	**30.60** - Close of voting/ comment period	**30.92** - CD referred back to Working Group		**30.98** - Project deleted	**30.99** - CD approved for registration as DIS
40 Enquiry stage	**40.00** - DIS registered	**40.20** - DIS ballot initiated: *12 weeks*	**40.60** - Close of voting	**40.92** - Full report circulated: DIS referred back to TC or SC	**40.93** - Full report circulated: decision for new DIS ballot	**40.98** - Project deleted	**40.99** - Full report circulated: DIS approved for registration as FDIS
50 Approval stage	**50.00** - Final text received or FDIS registered for formal approval	**50.20** - Proof sent to secretariat or FDIS ballot initiated: - *8 weeks*	**50.60** - Close of voting. - Proof returned by secretariat	**50.92** - FDIS or proof referred back to TC or SC		**50.98** - Project deleted	**50.99** - FDIS or proof - approved for publication
60 Publication stage	**60.00** - International Standard under publication		60.60 **– Intern. Standard published**				

STAGE	SUBSTAGE						
90 **Review stage**		**90.20** - International Standard under periodical review	**90.60** - Close of review	**90.92** - International Standard to be revised	**90.93** - International Standard confirmed		**90.99** - Withdrawal of Intern. Standard proposed by TC or SC
95 **Withdrawal stage**		**95.20** - Withdrawal ballot initiated	**95.60** - Close of voting	**95.92** - Decision not to withdraw International Standard			**95.99** - Withdrawal of International Standard

The standards and projects under the direct responsibility of IEC TC69 [15] already published are shown in Table VI and Table VII, this later with the stage abbreviations and starting dates. It should be noticed that even though the stages and associated documents have in most cases similar codes and names for both ISO and IEC (cf. Table II, and Table IV vs. Table VII**)**, they are not always exactly the same. A full list of IEC stage codes (as those in Table VII), its meaning and the equivalent harmonized stage codes can be found in [16].

TABLE VI. - Standards/Projects Published by IEC TC69 [15]

Reference, Edition, Date, Title
IEC TR 60783:1984 Edition 1.0 (1984-12-30) - Wiring and connectors for electric road vehicles. Stability date: 2017
IEC TR 60784:1984 Edition 1.0 (1984-12-30) - Instrumentation for electric road vehicles. Stability date: 2017
IEC TR 60785:1984 Edition 1.0 (1984-12-30) - Rotating machines for electric road vehicles. Stability date: 2017
IEC TR 60786:1984 Edition 1.0 (1984-12-30) - Controllers for electric road vehicles. Stability date: 2017
IEC 61851-1:2010 Edition 2.0 (2010-11-25) - Electric vehicle conductive charging system - Part 1: General requirements. Stability date: 2016
IEC 61851-21:2001 Edition 1.0 (2001-05-04) - Electric vehicle conductive charging system - Part 21: Electric vehicle requirements for conductive connection to an a.c./d.c. supply . Stability date:
IEC 61851-22:2001 Edition 1.0 (2001-05-04) - Electric vehicle conductive charging system - Part 22: AC electric vehicle charging station. Stability date: 2017
IEC 61851-23:2014 Edition 1.0 (2014-03-11) - Electric vehicle conductive charging system - Part 23: DC electric vehicle charging station. Stability date: 2016 (*has a Corrigendum 1*- COR1:2016)
IEC 61851-24:2014 Edition 1.0 (2014-03-07) - Electric vehicle conductive charging system - Part 24: Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging. Stability date: 2018 (*has a* COR1:2015)
IEC 61980-1:2015 Edition 1.0 (2015-07-24) - Electric vehicle wireless power transfer (WPT) systems - Part 1: General requirements. Stability date: 2018
IEC 62576:2009 Edition 1.0 (2009-08-18) - Electric double-layer capacitors for use in hybrid electric vehicles - Test methods for electrical characteristics. Stability date: 2017
IEC TS 62763:2013 Edition 1.0 (2013-12-10) - Pilot function through a control pilot circuit using PWM (pulse width modulation) and a control pilot wire. Stability date: 2017
ISO 15118-1:2013 Edition 1.0 (2013-04-16) - Road vehicles -- Vehicle to grid communication interface -- Part 1: General information and use-case definition. Stability date: 2016
ISO 15118-2:2014 Edition 1.0 (2014-03-31) - Road vehicles -- Vehicle-to-Grid Communication Interface -- Part 2: Network and application protocol requirements. Stability date:
ISO 15118-3:2015 Edition 1.0 (2015-05-26) - Road vehicles -- Vehicle to grid communication interface -- Part 3: Physical and data link layer requirements. Stability date:
ISO 17409:2015 Edition 1.0 (2015-10-23) - Electrically propelled road vehicles -- Connection to an external electric power supply -- Safety requirements. Stability date:

TABLE VII. - Standards/Projects under Development by IEC TC69 by May 2016 [15]

Project Reference and Title	**Stage**
IEC 61851-1 Ed. 3.0 - Electric vehicle conductive charging system - Part 1: General requirements	DEC - 2016-05
IEC 61851-21-1 Ed. 1.0 - Electric vehicle conductive charging system - Part 21-1 Electric vehicle onboard charger EMC requirements for conductive connection to a.c./d.c. supply	ADIS - 2015-08
IEC 61851-21-2 Ed. 1.0 - Electric vehicle conductive charging system - Part 21-2: EMC requirments for OFF board electric vehicle charging systems	A3CD - 2015-01
IEC 61851-23 Ed. 2.0 - Electric vehicle conductive charging system - Part 23: DC electric vehicle charging station	AMW - 2015-12
IEC 61851-23-1 Ed. 1.0 - Electric vehicle conductive charging system - Part 23-1: DC Charging with an automatic connection system	ANW - 2016-04
IEC 61851-24 Ed. 2.0 - Electric vehicle conductive charging system - Part 24: Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging	AMW - 2015-12
IEC 61980-1 Ed. 2.0 - ELECTRIC VEHICLE WIRELESS POWER TRANSFER (WPT) SYSTEMS - Part 1: General requirements	AMW - 2015-12
IEC 61980-1 am1 Ed. 1.0 - Amendment 1	AMW - 2015-12
IEC 62576 Ed. 2.0 - Electric double-layer capacitors for use in hybrid electric vehicles - Test methods for electrical characteristics	AMW - 2013-08
IEC 62831 Ed. 1.0 - User identification in Electric vehicle Service Equipment using a smartcard	ANW - 2012-09
IEC 62840-2 Ed. 1.0 - ELECTRIC VEHICLE BATTERY SWAP SYSTEM - Part 2: Safety requirements	RDIS - 2016-04
IEC 62982 Ed. 1.0 - Electric vehicles conductive charging system - Part 2x: Bi-directional d.c. charging station	PNW - 2015-02
IEC 62983 Ed. 1.0 - Electric vehicle charge station - Monitoring system	PNW - 2015-02
IEC/TS 61851-3-1 Ed. 1.0 - Electric Vehicles conductive power supply system - Part 3-1: General Requirements for Light Electric Vehicles (LEV) AC and DC conductive power supply systems	3CD - 2015-10
IEC/TS 61851-3-2 Ed. 1.0 - Electric Vehicles conductive power supply system - Part 3-2: Requirements for Light Electric Vehicles (LEV) DC off-board conductive power supply systems	3CD - 2015-10
IEC/TS 61851-3-3 Ed. 1.0 - Electric Vehicles conductive power supply system - Part 3-3: Requirements for Light Electric Vehicles (LEV) battery swap systems	ANW - 2013-01
IEC/TS 61851-3-4 Ed. 1.0 - Electric Vehicles conductive power supply system - Part 3-4: Requirements for Light Electric Vehicles (LEV) communication	A3CD - 2015-10
IEC/TS 61851-3-5 Ed. 1.0 - ELECTRIC VEHICLES CONDUCTIVE POWER SUPPLY SYSTEM - Part 3-5: Requirements for Light Electric Vehicles communication - Pre-defined communication parameters	A3CD - 2015-10
IEC/TS 61851-3-6 Ed. 1.0 - ELECTRIC VEHICLES CONDUCTIVE POWER SUPPLY SYSTEM - Part 3-6, Requirements for Light Electric Vehicles communication - Voltage converter unit	A3CD - 2015-10
IEC/TS 61851-3-7 Ed. 1.0 - ELECTRIC VEHICLES CONDUCTIVE POWER SUPPLY SYSTEM - Part 3-7, Requirements for Light Electric Vehicles communication - Battery system	A3CD - 2015-09
IEC/TS 61980-2 Ed. 1.0 - Electric vehicle wireless power transfer (WPT) systems - Part 2 specific requirements for communication between electric road vehicle (EV) and infrastructure with respect to wireless power transfer (WPT) systems	A3CD - 2016-01

IEC/TS 61980-3 Ed. 1.0 - Electric vehicle wireless power transfer (WPT) systems - Part 3 specific requirements for the magnetic field power transfer systems.	ACDV - 2015-12
ISO 15118-2 Ed. 2.0 - Road vehcles - Vehicle to grid communication interface - Part 2 Network and application protocol requirements	1CD - 2016-04
ISO 15118-4 Ed. 1.0 - Road Vehicles - Vehicle to grid communication interface - Part 4: Network and application protocol conformance test	A3CD - 2015-12
ISO 15118-5 Ed. 1.0 - Road vehicles - Vehicles to grid communication interface - Part 5: Physical and data link layer conformance tests	ACDV - 2015-03
ISO 15118-6 Ed. 1.0 - Road vehicles - Vehicle to grid communication interface - Part 6: General information and use-case definition for wireless communication	ADIS - 2016-01
ISO 15118-7 Ed. 1.0 - Vehicle to grid communication interface - Part 7: Network and application protocol requirements for wireless communication	A2CD - 2015-12
ISO 15118-8 Ed. 1.0 - Vehicle to grid communication interface - Part 8: Physical layer and data link layer requirements for wireless communication	ACDV - 2016-04
ISO 18246 Ed. 1.0 - Electrically propelled mopeds and motorcycles - Safety requirements for conductive connection to an external electric power supply	A2CD - 2015-06

4. Charging modes and plugs for EVs

There have been some difficulties on ensuring interoperability between chargers of EVs, as there are a lot of standards covering EVs conductive charging and its aspects, from different entities, as can be seen on Fig. 1 [17].

IEC 61851-1 defines **4 charging modes**. These can be described as follows: [18]

- Mode 1: Slow charging from a **household-type socket-outlet**. Maximum 16 A current for single-phase (250 V max.) or three-phase (480 V max.).
- Mode 2: Slow charging from a **household-type socket-outlet** with an **in-cable protection device**. Max. 32 A, for single-phase (250 V max.) or three-phase (480 V max.)
- Mode 3: Slow or fast charging using a specific **EV socket-outlet** with control and protection function installed (max. 32 A, for case B or 63 A for case C).
- Mode 4: Fast charging up to 400 A, 600 V, using an **external charger**, converting the AC mains power to DC.

This standard also define three connection cases:

- Case A - cable permanently attached to the EV;
- Case B – loose cable (not permanently attached to the EV neither to the electric vehicle supply equipment, EVSE)

  Case C - cable permanently attached to the charging station.

IEC 62196-1, IEC 62196-2 and IEC 62196-3, define the general requirements, dimensional compatibility and interchange-ability requirements for AC and DC plugs, socket-outlets and other accessories for conductive charging systems not exceeding 690 V AC (50-60 Hz) – 250 A; and 1500 V DC – 400 A). IEC 62196-2:2016 (AC) and 62196-3:2014 (DC) present different plug types:

- Type 1, single phase vehicle coupler, known as **Yazaki** or **SAE J1772**/2009. Used mainly in Japan and USA.
- Type 2, for single and three phase vehicle coupler and socket-outlet without shutters, according to VDE-AR-E 2623-2-2 specifications, known as **Mennekes**.
- Type 3, single and three phase vehicle coupler with shutters, like the **SCAME** plug from the EV Plug Alliance.
- Type 4, direct current coupler, known as **CHAdeMO**, used in Japan, from Japan Electric Vehicle Standard (JEVS) G105-1993 specifications.

In January 2013, the European Commission has announced the use of the "Type 2" plug as the common standard for the whole of Europe. Consequently, the production of Type 3 SCAME connectors seems to be abandoned by the end of 2015.

To allow both AC and DC charging of a vehicle, the Combo charging systems were created, as can be seen in Fig. 2. Combo1 is for the USA, resulting from a Type 1 (Yazaky) connector combined with a DC connector, and Combo2 is for Europe, combining a Type 2 (Mennekes) with to DC pins. Tesla Motors uses a 90 kW or 120 kW DC charging system called SuperCharger, using a

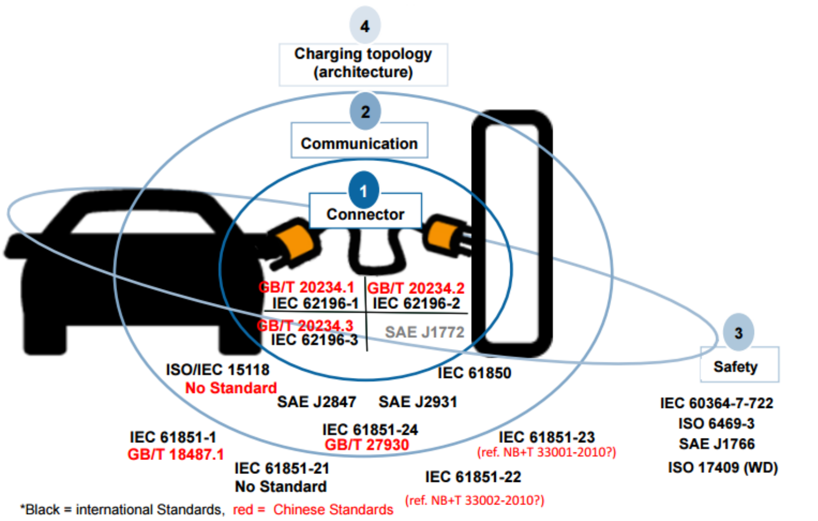

Fig. 1. Standards for EVs conductive charging [17].

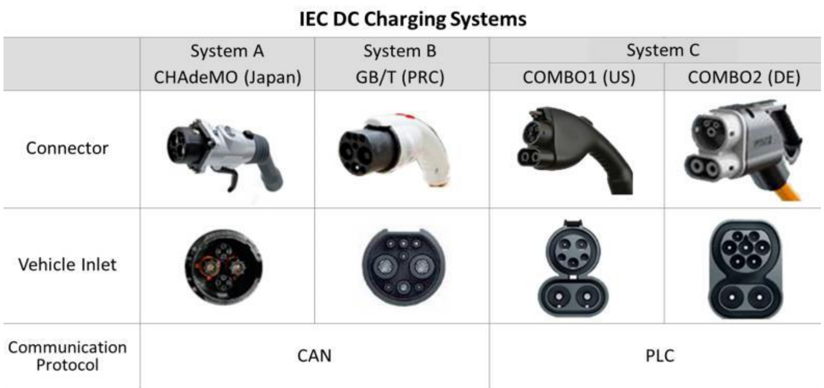

Fig. 2. Plugs and Sockets for DC Charging (Mode 4) [20].

modified Type 2 plug. This one allows for deeper insertion, and longer conductor pins, allowing for greater current and uses the same pins for AC or DC current.
A freely available explanation on this subject can be found in [18].
Some chargers on the market are provided with plugs for different standards (for example DCA – CHAdeMO; DCC - CCS/Combo; AC) [21].

Conclusions

Standardization is extremely important for EVs success and its integration on the grid, but it is an area that can be difficult to understand.
From Table IV and Table VII, it can be seen that the main areas currently under standardization work are conductive charging systems, wireless power transfer, electric double-layer capacitors for use in HEV, conductive power supply system for Light Electric Vehicles (LEV), EVs battery swap systems, vehicle to grid communication interface, safety specifications for electrically propelled road vehicles, and test specification for lithium-ion traction battery packs and systems.
Before concluding, it is important to clarify the differences between Standards and Regulations. Standards are voluntary documents produced by technical committees and approved by the representatives of the concerned and interested entities in the countries (namely the IEC National Committees or ISO national standards institutes). On the other hand, regulations are legally binding documents, which are issued by government. Nevertheless, our modern way of life would not be possible without standards and many standards are finally adopted by the countries as regulation.
In this paper, the EV standardization framework was presented on a compact form as well as the most important standardization activities going on at world, Europe. References were given allowing the non standards expert, to easily and quickly access the state of the standardization activities in the EVs frameworks also in the future.
The Standardization in Electric Vehicles is not an easy task. But a serious amount of effort is being put on this in order to ensure that there are no obstacles from this point of view to the EVs massive spread as a sustainable mobility solution.

Acknowledgement

This work has been partially supported by the Fundação para a Ciência e a Tecnologia (FCT) under project grant UID/MULTI/00308/2013.

References

[1] P. G Pereirinha, J. P. Trovão, "Multiple energy sources hybridization: the future of electric vehicles?", In: Z. Stević (Ed.), "New Generation of Electric Vehicles", InTech, Dec. 2012. DOI: 10.5772/53359.
[2] M. Messagie, F.-S. Boureima, T. Coosemans, C. Macharis and J. Van Mierlo, "A Range-Based Vehicle Life Cycle Assessment Incorporating Variability in the Environmental Assessment of Different Vehicle Technologies and Fuels", Energies, Volume 7, Issue 3, pp. 1467-1482, 2014.
[3] A. Nordelöf, M. Messagie, A.-M. Tillman, M. Söderman and J. Van Mierlo, "Environmental impacts of hybrid, plug-in hybrid, and battery electric vehicles — what can we learn from life cycle assessment?", Springer, The Int. J. of Life Cycle Assessment, ISSN 0948-3349, DOI 10.1007/s11367-014-0788-0, published on-line 21 August 2014.
[4] T.R. Hawkins, B. Singh, G. Majeau-Bettez and A.H. Strømman, "Comparative environmental life cycle assessment of conventional and electric vehicles". J. Ind. Ecol. 2013, Vol. 17, 53–64.
[5] R. Nealer, D. Reichmuth and D. Anair, "Cleaner Cars from Cradle to Grave (2015) - How Electric Cars Beat Gasoline Cars on Lifetime Global Warming Emissions", Union of Concerned Scientists, Nov. 2015. Available at www.ucsusa.org/EVlifecycle.
[6] J. MacDonald, "Electric vehicles to be 35% of global new car sales by 2040", Bloomberg New Energy Finance, press release, Feb 25, 2016, available at http://about.bnef.com/press-releases/electric-vehicles-to-be-35-of-global-new-car-sales-by-2040.
[7] P. G. Pereirinha and J. P. Trovão, "Standardization in Electric Vehicles", 12th Portuguese-Spanish Conference on Electrical Engineering, XIICLEEE, Ponta Delgada, Portugal, June 30 –July 2, 2011.
[8] International Electrotechnical Commission (IEC) web-site, www.iec.ch.
[9] International Organization for Standardization (ISO), www.iso.org.
[10] "ISO/IEC Agreement Concerning Standardization of Electrotechnology for Road Vehicles and the Cooperation Between ISO/TC 22 "Road Vehicles" and IEC Technical Committees", March 2011, available at www.iec.ch/about/globalreach/partners/international/pdf/iso-iec_agreement_2011.pdf
[11] Resolution of the 32nd meeting of ISO/TC22/SC21 and of the kick-off (1st) Meeting of ISO/TC22/SC37, Troy (MI) Big Beaver Road, USA, March 06, 2015.
[12] ISO/IEC Directives, Part 1: Procedures for the technical work (12th ed., May 2016). Available at http://www.iec.ch/members_experts/refdocs/iec/isoiecdir-1%7Bed12.0%7Den.pdf
[13] ISO/IEC Directives, Part 2: Principles and rules for the structure and drafting of International Standards (7th edition, 2016).
[14] ISO, "Standards and projects under the direct responsibility of the ISO/TC 22/SC 37 Secretariat", ISO/TC 22/SC 37 - Electrically propelled vehicles", http://www.iso.org/iso/home/store/catalogue_tc/catalogue_tc_browse.htm?commid=5391154.
[15] IEC - TC 69, Electric road vehicles and electric industrial trucks, Projects / Publications, www.iec.ch/dyn/www/f?p=103:23:0::::FSP_ORG_ID,FSP_LANG_ID:1255,25
[16]"Stage Codes", IEC, www.iec.ch/standardsdev/how/processes/stage_codes.htm
[17]David Reeck, International Programs to Promote Electric Vehicles, EV Roadmap 7 Conf, , Portland, USA, July 24-25, http://evroadmapconference.com/program/index14.php
[18] "IEC 62196", Wikipedia, http://en.wikipedia.org/wiki/IEC_62196
[19]"EU launches clean fuel strategy". European Commission. 2013-01-24. press release. IP/13/40
[20]Mark Kane, "CHAdeMO Officially Recognized as International DC Charging Standard by IEC", InsideEVs, Mach 2014, http://insideevs.com/chademo-officially-recognized-international-charging-standard-iec
[21]QC45 Charger, Efacec Electric Mobility http://electricmobility.efacec.com/ev-qc45-quick-charger