SMART EV·VC

Facts & Current Status of the Standardization for Electric Vehicles:

Batteries and Charging Infrastructure

Content

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1 Introduction

Standardization is a key factor for a successful market entry of new technologies and product. Full Electric Vehicles (FEV) form no exception on this rule, and given these vehicles' complexity and novelty a broad range of features, components and systems need to be standardized. This would lower production cost, increase interchangeability and compatibilities, and sustain market penetration. This brochure aims to give a basic overview of available standards, focusing on two systems that are essential for the operation of a FEV: batteries and charging infrastructure.

2 Standardization bodies

Standardization, on a global level, is mainly driven by two institutions: the International Electrotechnical Commission (IEC), founded in 1904, deals with electronics and electrical goods, whereas the International Organization for Standardization (ISO), founded in 1948, deals with all other technologies. Since the FEV introduces electric traction technology in a road vehicle environment, it represents a mixed technology, being both a ”road vehicle” and an ”electrical device. Hence standardization matters are currently divided between the two organizations in the following way:

- ISO: takes up the work related to the electric vehicle as a whole
- IEC: takes up the work related to all the electric components and electric supply infrastructure

Within Europe, CENELEC and CEN operate as dependants of IEC and ISO for electric vehicles. Both are active in electric vehicle standardization, through their technical committees CENELEC TC69X and CEN TC301. However, much of this work is parallel to the global standardization work, where the European standards created superseded by international standards when these are available (such as prEN50275 vs. IEC61851 and EN1987 vs. ISO6469). The Electro-Mobility Coordination Group constituted by CEN and CENELEC has the aim to s±upport the coordination of standardization activities during the critical phases (such as writing new standards or updating existing standards), and to make recommendations accordingly . The Coordination group communicates with the relevant standardization committees 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 with the corresponding European technical committees within the framework of CENELEC. An overview of these committees is given in Figure 1.

[1] http://www.cencenelec.eu/standards/Sectors/ElectricVehicles/Pages/default.aspx

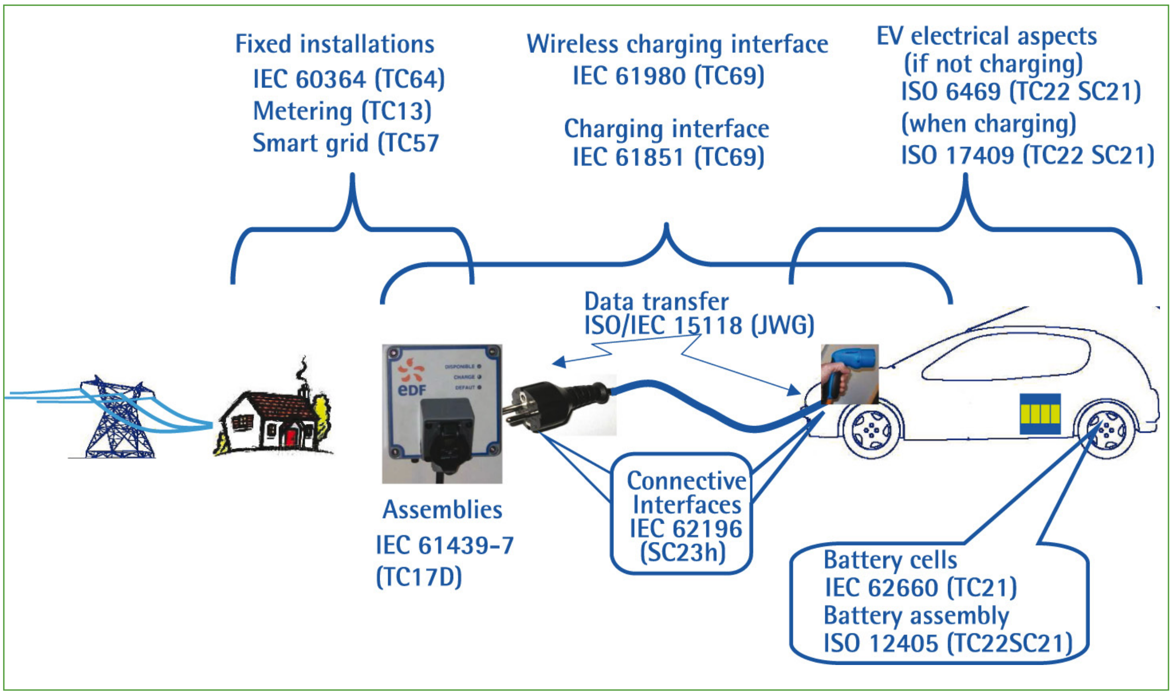

Figure 1: Overview of Standardization Committees

3 Standards

As with all standardization matters, the standards for FEV's pertain to the three main pillars of the so-called "house of standardization": safety, compatibility and performance (Figure 2). All discussed standards in this document are related to these three aspects. They can be classified in two main groups: charging infrastructure standards and battery standards. For charging infrastructure the technology domain are further divided in Basics, Communications and Accessories subdomains.

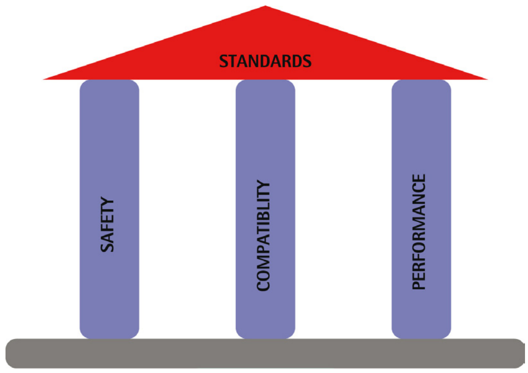

Figure 2: The house of standards

3.1 Standards for charging infrastructure

On the 29th of June in 2010 the DG Enterprise & Industry of the European Commission issued the Mandate M468 concerning the charging of electric vehicles to CEN and CENELEC, as well as to the telecommunications standards to the European Telecommunications Standards Institute (ETSI). Its scope was to develop or 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 vehicles (if the charger is not on-board), 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 (EMC) of the charger of electric vehicles in the field the low voltage and EMC directives.

3.1.1 Charging power levels

Essential in the specification of charging infrastructure is the power level. Several power levels can be defined according to the power taken from the grid and the associated charging speed possible. However it should be considered the use of terms like ”semi-fast” or ”fast” in this context, referring to the charging speed of typical vehicles like cars or small delivery vans. Such a typical medium-sized vehicle has a power consumption of 200Wh/km, and hence needs 10kWh to cover 50km distance. For smaller vehicles such as two-wheelers, the power of a standard 16A outlet may already allow a ”fast” charge, whereas for a full-size bus a 22kW connection will just be a ”normal” charge.

”Normal” charging

Normal charging can be understood as using a power level corresponding to standard power outlets as typically available in residential installations. This concept corresponds to Level 1 charging defined in the United States. The rating of standard power outlets varies in different regions of the world. In most European countries, the standard outlet is rated 230V, 16A, yielding up to 3,7kW which allows the 10kWh of a typical medium-sized vehicle to be recharged in under three hours, and offers adequate power for overnight charging (typical practice for both private and commercial electric vehicles). In some countries however the standard outlets are lower rated (e.g. United Kingdom 13A, Switzerland 10A). The ”normal” charging is rated at 230V, 16A.

”Semi-fast” charging

Semi-fast or accelerated charging is to be understood as making use of current levels exceeding those of a standard domestic outlet, but which could be readily made available in a typical residential or commercial setting. This corresponds to Level 2 charging in the USA. It can be achieved either with a higher current single -phase connection or with a three-phase connection. Semi-fast charging allows charging a medium sized vehicle in just under one hour for a range of 50km. The power level of 22kW is generally accepted as the upper limit of ”semi-fast” charging. An overview of power levels for normal and semi-fast charging is given in Table 1.

	Voltage	Phases	Current	Power (kW)	Copper (mm^2)	kW/mm^2
Standard	230	1	16	3,7	5	0,74
Semi-fast	230	1	32	7,4	12	0,62
Semi-fast	230	3	16	6,4	7,5	0,85
Semi-fast	400	3	16	11,1	7,5	1,48
Semi-fast	400	3	32	22,2	18	1,23

Table 1: Power levels for charging (cos φ =1), including needed copper section for the conductor, as well as the relation power/copper section.

“Fast” charging

For ”fast” charging (called ”Level 3” charging in the USA), higher power levels are used. This creates the need for specific infrastructure beyond standard domestic or industrial socket-outlets, with typically charging power levels higher than 22 kW. The charging can be either performed with a DC or an AC connection between the vehicle and the charging post. In the DC case, a fixed battery charger (rectifier) has to be connected to the battery, and heavier and more expensive fixed infrastructure is thus needed. The DC charging stations may either be:

- Regulated, where the charging current dispensed by the charger is controlled by a communication signal from the vehicle, or unregulated, where this current is controlled on-board the vehicle; this latter case corresponding in fact to a DC grid.

- Isolated, where there is a galvanic separation between the DC connection and the AC grid (through transformer) or non-isolated where the DC connection is galvanically connected to the AC grid.

Most DC charging stations now used are of the regulated and isolated variety.
For AC fast charging the rectifying is done on-board the vehicle, most commonly using the traction inverter. This is able to recharge the battery at a high current (for regenerative braking) and can also be fed by the grid. Fast charging infrastructure is being proposed for power levels up to 250kW claiming to be able to charge an electric vehicle in less than 10 minutes, which is comparable with the refueling time of a gasoline powered legacy vehicle.

3.1.2 Standards for conductive charging:

The main reference documents for conductive charging are the ***IEC61851*** family of Standards. ***IEC 61851*** applies to the electric vehicle as well as to the charging station. In addition, the emergence of fixed charging infrastructure for electric vehicles has also prompted other committees to work on the subject. In this context ***IEC61439-7*** (”Low-voltage switchgear and controlgear assemblies — Part 7: Assemblies for specific applications such as marinas, camping sites, market squares, electric vehicles charging stations”) was issued. It has to be used with the general standard ***IEC61439-1***.

3.1.2.1 Charging modes for conductive charging

Nowadays, most of the charging is done by conductive means, i.e. having a physical connection between the vehicle & the related infrastructure. The international standard ***IEC61851-1*** introduced the definition of the so-called charging modes, related to the actual conductive charging infrastructure. Four modes have been defined:

Mode 1 charging refers to the connection of the EV to the AC supply network 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.

Mode 2 charging refers to the connection of the EV to the AC supply network and 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.

Mode 3 charging involves the direct connection of the EV to the AC supply network utilizing dedicated electric vehicle supply equipment. The standard ***IEC61851-1*** mandates control pilot protection between equipment permanently connected to the a.c. supply network and the electric vehicle. This function is typically performed through an extra conductor in the charging cable assembly, in addition to the phase(s), neutral and earth conductor. The use of a control pilot function with fourth wire is also included in the SAE standard ***J1772***.

Mode 4 charging is defined as the indirect connection of the EV to the AC supply network (mains) utilizing an off-board charger where the control pilot conductor extends to equipment permanently connected to the AC supply. This pertains to DC charging stations, which are mostly used for fast charging. As the charger is located off-board, a communication link is necessary for regulated DC charging stations 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.

3.1.2.2 Standards for inductive charging

Inductive charging is defined as the transfer of energy from the supply network to the vehicle in an electromagnetic way, using a two-part transformer with the primary connected to the network and the secondary installed on the vehicle. Charging can be performed after juxtaposition of the two parts. Inductive charging systems have recently known a renewed interest and the standardization work on the subject has been revived. General requirements of the wireless charging systems, particularly highlighting the safety aspects involved with exposure to magnetic fields in the vicinity of the inductive coils are describe in the first CD for ***IEC61980-1***, circulated in December 2012.

3.1.2.3 Battery exchange systems

A particulary fast replenishment of the energy on board of the vehicle can be performed by a fast replacement of the battery pack with a freshly charged one. This technology, has now gained new interest for general use. Its implementation however will entail specific standardization problems. Standardization work on battery exchange has been taken up in 2012 with a new project ”Electric vehicle battery exchange infrastructure safety requirements”, which was circulated as NP[2] and accepted. This initiated the drafting of the future standard ***IEC62840*** applying to battery swap infrastructure for electric vehicles equipped with lithium-ion switchable and rechargeable battery packs.

3.1.2.4 EMC issues

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 the one hand by the EMC directive ***2004/108/EC*** which pertains to electric and electronic equipment, and on the other hand by the vehicle EMC directive ***2004/104/EC*** which pertains to road vehicles. Furthermore there are numerous international standards published by IEC, ISO and CISPR dealing with the matter. New standardization work on EMC for electric vehicle charging were undertaken with the revision of ***IEC61851 (Part21)***.

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2 IEC62840/NP, Electric vehicle battery exchange infrastructure safet requirements, No. 69/217/NP, IEC TC69, 2012.

3.1.3 Communication and grid management

Communication between the vehicle and the charging is defined in ***IEC61851***. Whereas In Mode 1 or Mode 2 charging there is no communication at all, for Mode 3 the communication through the control pilot function is described in Annex A of ***IEC 61851-1***. For Mode 4 the new developments in the field of DC charging have led to the drafting of ***IEC61851-24*** on a global level.
In addition, 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, including roaming.
- Charge cost optimization by choosing the most appropriate time window where electricity rates are the lowest;
- Grid load optimization by controlling charger capacity 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.

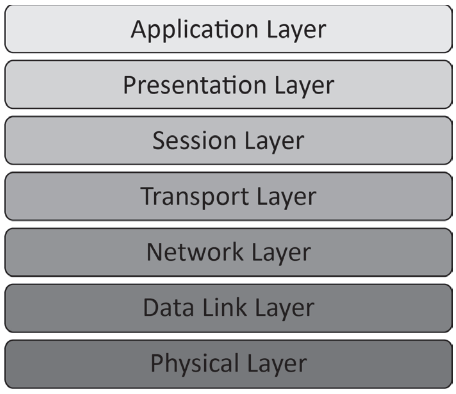

Figure 3: Open System Interconnection Layers

Communication protocols are based on the well-known 7-layer Open System Interconnection (OSI) reference model Figure 3. Standardization on this matter can be found in the family of standards called ***ISO/IEC 15118,*** which is oriented of the charging of electric road vehicles. However this standard is open for other vehicles as well.

3.1.4 Accessories for charging

Essential for the succesfull rol-out of electric vehicles is the standardisation of charging accesories, increasing the users flexibility for charging at variuos locations and variuos providers.

3.1.4.1 Connection to the AC network: plug and socket outlet

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. However, these domestic plugs are not really suited for the heavy-duty operation of electric vehicle charging, and hence, a better alternative is to use industrial plugs and sockets as defined by the international standard ***IEC60309-2***. However, the use of a physical control pilot conductor (Mode 3 and 4) 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 gives general functional requirements. It integrates general requirements from the industrial plug standard ***IEC60309-1***; with the electric vehicle requirements of ***IEC61851-1***, while physical dimensions for AC accessories are treated in Part 2, which presents standard sheets for several types of plugs and socket-outlets such as

- Type 2: three-phase plug rated for currents up to 63A, and with two auxiliary contacts. It is based on a realisation by the german company Mennekes. The need for three-phase accessories was expressed by 29 European car manufacturers and utilities, recognizing the potential benefit of three-phase charging (Figure 4).
- Type 3: also a three-phase type, and based on a design by italian company SCAME further adopted by the ”EV Plug Alliance” (Figure 5).

The proposed European directive[3] on the deployment of alternative fuels infrastructure however prescribed the use of Type 2 accessories as the standard solution for Europe. Charging points shall comply with this standard by the end of 2015.

Figure 4: Type 2 plug

Figure 5: Type 3 plug and socket outlet

3.1.4.2 Connection to the vehicle: vehicle inlet and connector

The document ***IEC62196-2*** also describes accessories for the vehicle side. Connectors can be made according to the Type 2 and Type 3 geometries intermateable; however plug-side accessories are not intermateable with the vehicle side accessories. In addition the standard also describes the Type 1 single phase coupler 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. This solution is featured in SAE-J1772 [22] and based on a proposal made by the Japanese company Yazaki (Figure 6). The automobile industry is presently mounting both Type 1 and Type 2 inlets on cars and light trucks, depending of the original market of the vehicle. In Europe, both types can thus be found.

Figure 6: Type 1 connector

Figure 7: Combo connector example

Accessories for DC charging are treated in ***IEC62196-3***. The standard presents three families of connectors, corresponding to the three charging protocols described in parts 23 and 24 of ***IEC61851***

- the DC connector/inlet proposed by the CHAdeMO association
- the DC connector/inlet proposed by the Chinese NC
- the "Combo" connector/inlet, encompassing both AC (Type 1 or 2) and DC connections in one unit (Figure 7). The inlet can be used for AC with a Type 1 or 2 connector or for DC with the combo connector. The proposed European directive[3] prescribes the use of "Combo type 2" connectors for DC charging stations. Fast charging points shall comply with this standard by the end of 2017.

3.2 Standards for battery systems

Standardizations of battery systems may address three main subject areas related to:

- Design
- Safety
- Performance

3.2.1 Battery design standards

3.2.1.1 Lead acid batteries

Battery standards have been drafted since a long time, particularly for lead acid traction batteries. The main standards here are the ***IEC 60254*** series, with the first part describing battery performance tests, and the second part defining standard cell sizes. These standards are primarily aimed at traction batteries such as used in industrial electric vehicles like forklift trucks. For these applications, the lead-acid traction battery is a mature commercial product. The standard ***IEC60254-2*** defines standard dimensions for lead-acid traction cells. The document features specific European, Japanese and North American series.

[3] Proposal for a directive of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, No. 2013/0012(COD), European Commission, 2013

3.2.1.2 Lithium batteries

Unlike lead-acid, lithium is a technology still in development, and it is too early to impose strict dimensional standards, which would stifle technological development. Lithium-ion traction cells are being developed in various geometries (cylindrical, prismatic or pouch) and cell capacities. At this moment, the publicly available specification (i.e. not a full edged standard) ***ISO/IEC/PAS 16898*** Electrically propelled road vehicles Battery system design - Requirements on dimensions for lithium-ion cells for vehicle propulsion, is being developed. It defines designations and markings of cell dimensions, configurations and position of terminals and venting mechanism (which are to be used for design of battery packs) as well as dimensions for lithium-ion cells and the location of the connection terminals to be used in electrically propelled road vehicles. The PAS does not aim to give specs for inner construction, cell chemistry, electrical characteristics and any further properties, nor relations between dimensions and capacity of cell as the performance of secondary lithium-ion batteries for vehicle propulsion is still being improved quickly. Regarding battery module sizes for exchange systems, standards have been proposed on a national level in China.

3.2.2 Safety standards

3.2.2.1 RESS safety in the vehicle

The safety of the rechargeable energy storage systems (RESS) in the vehicle is treated by ***ISO 6469- 1*** *Electric road vehicles Safety specifications - Part 1: On-board rechargeable energy storage system*. This document requires a minimum insulation resistance of 100/V and defines minimum clearance and creepage distances. It also features some specifications for gas emission and RESS crash requirements.

3.2.2.2 Safety of lead acid and alkaline batteries

Safety of traction batteries is described in ***IEC 62485-3***. This document is focusing on batteries with aqueous electrolyte (acid or alkaline) and thus gives special interest to ventilation and gassing issues. It is based on industrial practices for battery-electric industrial vehicles.

3.2.2.3 Safety of lithium battery systems and cells

The safety aspects of lithium traction battery systems are treated in parts 1 and 2 of ***ISO 12405***, *Electrically propelled road vehicles - Test specification for Lithium-ion traction battery packs and systems*. These documents feature abuse tests, thermal and humidity tests and vibration tests. The third part of ***ISO 12405***, Safety performance requirements, is now circulating as DIS. Unlike parts 1 and 2, this document defines actual requirements. Whereas ***ISO12405*** deals with battery systems, ***IEC62660-2*** *Secondary batteries for the propulsion of electric road vehicles Safety testing for lithiumion cells and batteries*, deals with individual cells and modules, defining mechanical, thermal and electrical tests, whileas part 3 of the standard, now under development, states actual requirements.

3.2.2.4 Post-crash safety

The new part 4 of ***ISO 6469*** deals with post-crash safety requirements for electrically propelled road vehicles, being aimed at safe intervention by emergency services. It shall refer to existing regulations, not adding new crash test scenarios. Requirements focus among others on leakage of electrolyte and absence of hazardous voltages.

3.2.2.5 Battery transportation safety

For the sake of transportation as goods, lithium-ion batteries are classified as Class 9 hazardous goods, dealt with by ***UN regulations 3480 and 3481***. These documents define a number of tests which must be passed to allow batteries for transport.

3.2.3 Battery performance standards

The main performance parameters for RESS in electrically propelled vehicles are the specific energy (Wh/kg), defining the vehicle range, and the specific power (W/kg), defining vehicle performance. These parameters are defined through standardized test cycles which must emulate the actual use of the RESS.

3.2.3.1 Performance of EV batteries

To take into account the specific application of electric vehicles, dynamic test cycles shall be used. These are considered in ***IEC 61982*** *Secondary batteries (except lithium) for the propulsion of electric road vehicles performance and endurance tests*, the revised edition of this standard published in one part (first edition had three parts). This generic standard introduces the ”dynamic discharge performance test” and the ”dynamic endurance test”, with test cycles emulating acceleration, cruising and regenerative braking. It also introduces a vehicle-based approach, with profiles based on power rather than current, or energy rather than capacity. For hybrid applications, power and internal resistance tests are defined.

3.2.3.2 Performance of lithium batteries

The approach here is two-fold, with ISO focusing on the battery system, and IEC on the battery cells. The ***ISO 12405*** standard *Electrically propelled road vehicles Test specification for Lithium-Ion traction battery systems comes* in two parts: High-power applications and high-energy applications. The performance of battery cells is described by the ***IEC standard 62660-1***, *Secondary batteries for the propulsion of electric road vehicles, Performance testing for lithium-ion cells and batteries*. Test cycles defined in this standard are consistent with ***ISO 12405***, making the two documents complementary. An example of such a cycle can be seen in Figure 8.

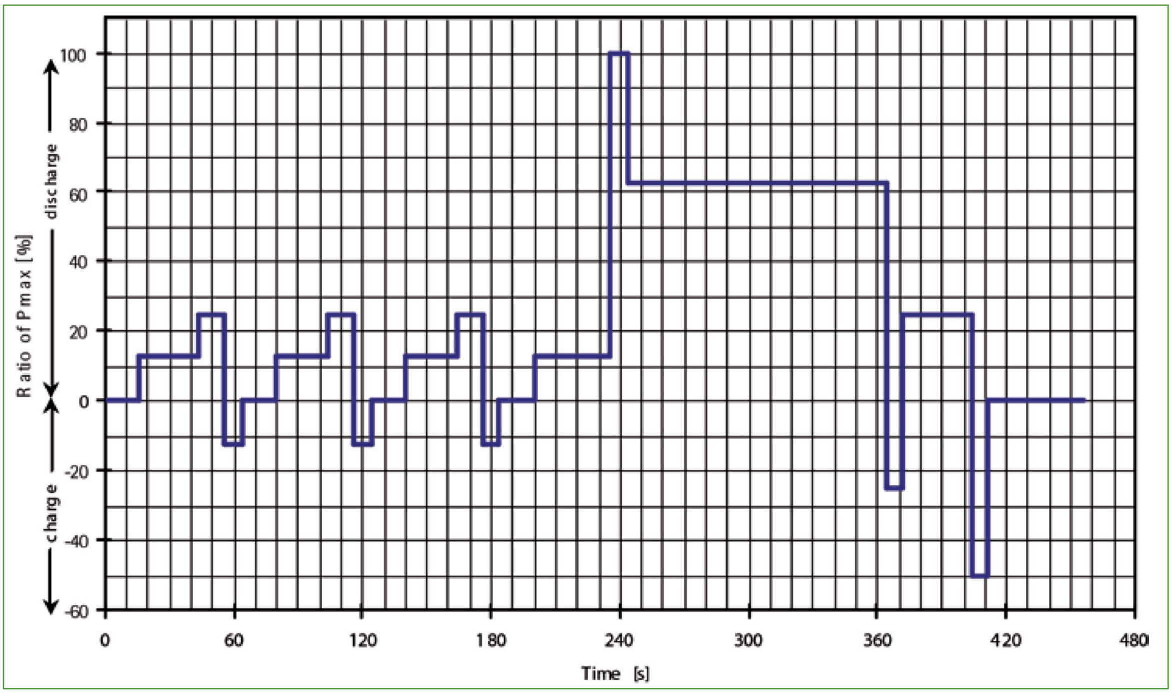

Figure 8: Test cycle for ISO12405-2 en IEC62660-1

3.2.3.3 Performance of electric double-layer capacitors

Electric double-layer capacitors are characterized by a very high power density. Performance tests are described in ***IEC 62576***, *Electric Double-Layer Capacitors for Use in Hybrid Electric Vehicles - Test Methods for Electrical Characteristics*.

3.2.3.4 Future developments

New standards may be developed if the need and the demand arise. On one hand this may be the case for new components such as ”lithium capacitors”, for which the existing standard measurement procedures are not suitable. On the other hand, one may consider new applications such as the ”second life” batteries used for stationary applications, where appropriate standard tests for state of health measurement and specific load cycles for the application have to be defined.

4 Overview standards

An overview of the stage of abovementioned standards is given in Table 2 . IS, PAS, FDIS and in certain cases DIS/CDV are for sale on the internet. For CD please contact yout national committee.

Body	Document	Edition	Stage	W o r k i n g document	Date
IEC	60254-2	4	IS		2008-02
IEC	60309-2	4,2	IS		2012-05
IEC	61439-1	2	IS		2011-08
IEC	61439-7	1	FDIS	17D/478/.FDIS	2013-06
IEC	61851+1	2	IS		2010-11
IEC	61851-1	3	2CD	69/250/CD	2013-06
IEC	61851-21-1	1	2CD	69/266/CD	2013-09
IEC	61851-21-2	1	3CD	69/245/CD	2013-05
IEC	61851-23	1	RDIS	69/227/CDV	2013-09
IEC	61851-24	1	RDIS	69/223/CDV	2013-09
IEC	61982	1	IS		2012-04
IEC	61980-1	1	CD	69/236/CD	2011-07
IEC	62196-1	2	IS		2011-10
IEC	62196-1	3	CDV	23H/296/CDV	2012-10
IEC	62196-2	1	IS		2011-10
IEC	62196-3	1	CDV	23H/292/CDV	2013-09
IEC	62485-3	1	CDV	21/801/CDV	2012-03
IEC	62660-2	1	IS		2010-12
IEC	62660-3	1	CD	21/817/CD	2013-09
IEC	62840	1	NP	69/217/NP	2012-09
ISO	6469-1	1	IS		2009
ISO	12405-1	1	IS		2011
ISO	12405-2	1	IS		2011
ISO	12405-3	1	DIS		2013-06
ISO/IEC	15118-1	1	IS		2013
ISO/IEC	15118-2	1	FDIS		2013
ISO/IEC	15118-3	1	DIS		2013
ISO/IEC	16898	1	PAS		2012

Table 2: Stage of the standards

With :

NP:	New work proposal
CD:	Committee draft
CDV:	Committee draft for voting (IEC)
DIS:	Draft international standard (ISO), =CDV
FDIS:	Final draft international standard
RDIS:	Tekst for FDIS registered
IS:	International Standard (published)
PAS:	Publicly available specification (published)

5 Additional information

More information can be found at following organizations:

- Global Standardization Bodies:
  - Electro Technical Commission (IEC), 3 rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland, + 41 22 919 02 11, info@iec.ch, www.iec.ch
  - International Organization for Standardization (ISO), 1 ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, +41 22 749 01 11, central@iso.org, www.iso.org
- European standardization Bodies:
  - CENELEC: 17 Avenue Marnix, BE-1000 Brussels, Belgium, +32 2 519 68 71, research@cencenelec.eu, www.cenelec.eu
  - CEN 17 Avenue Marnix, BE-1000 Brussels, Belgium, + 32 2 550 08 11, info@cen.eu, www.cen.eu
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