# Trends and Development Status of IEC Global Electric Vehicle Standards

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## Abstract
*International standardization is an essential issue in allowing the development and deployment of new technologies such as electrically propelled vehicles (battery-electrics, hybrids and fuel cell vehicles). Ongoing work in the field by the International Electrotechnical Commission focuses both on energy storage and charging infrastructure. This paper presents current developments in the field.*

## Keywords
*standardization, infrastructure, battery, electric vehicle, safety*

## 1. INTRODUCTION
In urban traffic, due to their beneficial effect on environment, electric vehicles are an important factor for the improvement of traffic and more particularly for a healthier living environment. Electrically propelled vehicles make use of energy sources which need access to the electric supply network for recharging, and thus need suitable infrastructures. [Van den Bossche, 2010]
It is clear that international standardization will be a key element in making such development possible. The international standardization and regulation work on these subjects is thus developing worldwide with a fast pace, with the main standardization work being performed by IEC TC69 (charging infrastructure), IEC TC21 (batteries) IEC SC23H (plugs and connectors) and ISO TC22 SC21 (vehicle issues) as well as several joint working groups between these committees. The standards being developed actually address the three main pillars of standardization – safety, compatibility and performance.
The main actors involved in the international standardization in the field are shown in Figure 1.

## 2. ENERGY STORAGE STANDARDIZATION
The standardization scene for automotive traction batteries presents a complicated challenge: On one hand one has to take into account the desired application. The charge and discharge characteristics of batteries in hybrid applications, where the battery is intended fore mostly as power storage, differ strongly from battery-electric applications, where the battery acts as energy storage, so specific test cycles have to be defined. Furthermore, battery characteristics, particularly concerning safety, can be regarded from the viewpoint of the battery or from the viewpoint of the system. The first approach is the traditional battery cell and module standardization as performed by the IEC battery com-

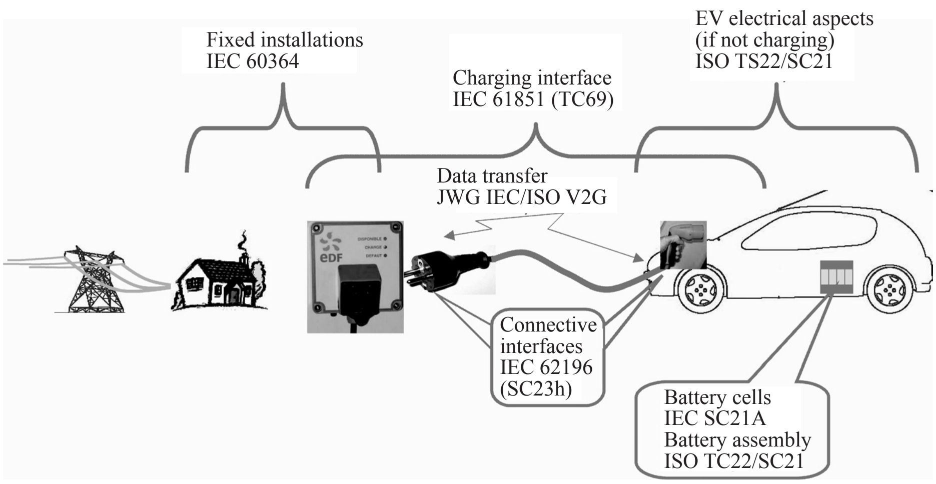


**Fig. 1** Actors in standardization (source EDF)

mittees. The automotive sector however, represented in the relevant ISO committees, wants to standardize the battery system, as a component of the vehicle traction system. A consensus agreement has led to the drafting of specific standards:

- ISO 12405 ''Electrically propelled road vehicles - Test specification for lithium-ion traction battery packs and systems'' for which there will be two parts, taking into account the specific needs of high power and high energy systems.
- IEC62660-1, Secondary batteries for the propulsion of electric road vehicles – Performance testing for lithium-ion cells and batteries"

These documents focus respectively on the battery system (Figure 2) and on the battery cells and modules, presenting test methodologies appropriate for various applications.

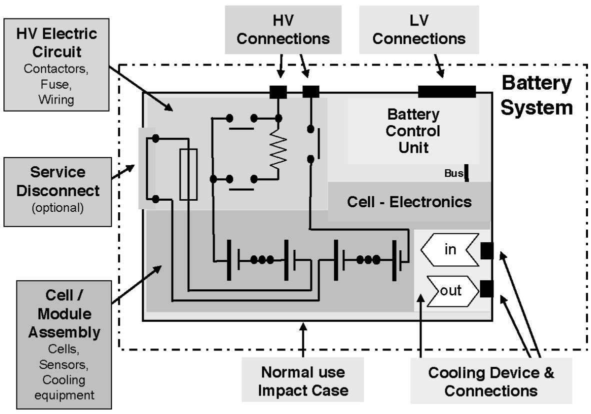


**Fig. 2** Battery system [IEC 12405]

For high power applications, it is necessary to determine pulse power capability of the battery, with specific cycles to measure the momentary voltage drop during discharge or charge microcycles, which allows to assess the internal resistance and maximum power for several burst times, and cycle tests mimicking the sequencing of short discharge and charge microcycles with high current bursts as are typically found in the operation of a battery in a hybrid vehicle. In the typical hybrid operation, the battery state of charge varies in a window from 30 to 80%, with the battery never fully charged (which means it would not accept any braking power) nor fully discharged (when it would be unable to provide acceleration power). It is clear that this mode of operation can not be properly described by the standard capacity tests developed for battery-electric vehicles. This evolution of state of charge is shown in Figure 3.

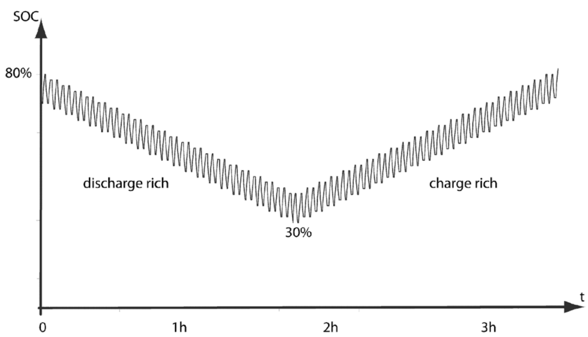


**Fig. 3** SOC evolution for hybrid test [IEC12405]

The tests for battery-electrics and plug in hybrids however consider a charge-depleting operation mode, and also feature a hybrid microcycle characterised by charge and discharge bursts with an overall charge balance of near zero (actually slightly positive to take into account charge efficiency), corresponding to the battery use in a charge sustaining mode with the on-board range extender in use.

In all cases the proposed cycles mimic the real life use of the battery in a road vehicle, presenting power peaks for acceleration, as well as regenerative braking. An example is shown in Figure 4.

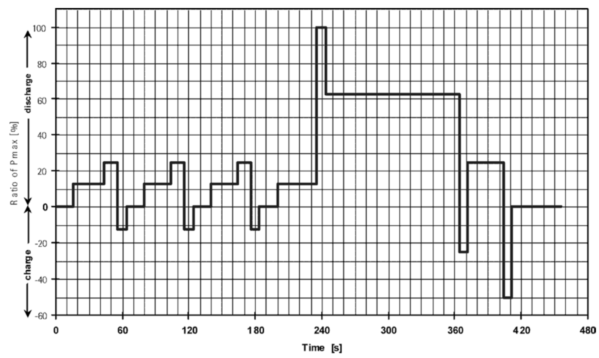


**Fig. 4** Microcycle for dynamic discharge [IEC 62660-1]

Both parts of ISO 12405, as well as IEC 62660-5, also deal with safety, providing a set of tests to assess cell behaviour when subject to abuse conditions, both mechanical (vibration, shock and crush), thermal and electrical (short circuit and overcharge), with tests results in ascending order of severity going from no effect to explosion of the cell. The main difference between the ISO and the IEC documents is that the latter is focused on the cell itself which is subject to abuse directly and that safety functions of the battery system which may cut off a circuit for example are not considered.

The publication of these international standards will provide valuable guidelines for component and system developers as well as allowing performance evaluation for systems using electric double-layer capacitors or performance batteries.

As the lithium technology is still new and in full development, it is generally considered too early to draft full dimensional standards as they exist for mature technologies like lead batteries. Some first steps in this direction are being taken by the end of 2010 however.

## 3. CHARGING INFRASTRUCTURE STANDARDS

The main international standard concerning conductive charging is the IEC 61851. In order to present an easy classification, it has defined several charging modes.

### *3.1 Mode 1 charging*

Mode 1 charging refers to the connection of the electric vehicle to the a.c. supply network utilizing standard (domestic or industrial) socket outlets. At this time, Mode 1 charging is the most common option for electric vehicles. The safe operation of a Mode 1 charging point depends however 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 without proper earthing, a hazardous situation for indirect contact could occur with a single earth fault within the vehicle.

In most countries, residual current devices (RCDs) are now prescribed for all new electric installations. However, still a lot of older installations are without RCD, and it is often difficult for the electric vehicle's user to know, when plugging in the vehicle, whether or not an RCD is present. Mode 1 has therefore been outlawed in a number of countries such as the United States, and restricted to private premises in other countries like Italy.

In countries where the use of Mode 1 charging is allowed, it will remain the most widespread charging mode for private premises (including residential garages as well as corporate parking lots) due to its simplicity and low investment cost. With a proper and up-to-date electrical installation, Mode 1 allows charging in full safety. Mode 1 charging can be compared to electric engine preheating systems, which are in common use in Nordic countries for many years without any safety problems.

However, the uncertainty faced by the user about the presence of an RCD when plugging in the electric vehicle in an arbitrary standard outlet results in a potential hazard. For this reason, vehicle manufacturers, because of liability issues and the risk for bad publicity tend to steer away from Mode 1 charging in the long term.

### *3.2 Mode 2 charging*

Mode 2 charging connection of the electric vehicle 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 with a control pilot conductor (see below) between the electric vehicle and the plug or control box.

The introduction of Mode 2 charging was initially mainly aimed at the United States, and initially considered a transitional solution awaiting the development of dedicated infrastructure.

Recently however, Mode 2 has gained a renewed interest also in Europe, with the intent replacing Mode 1 for charging at nondedicated outlets.

Besides the obvious drawbacks of using an in-cable control device, 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.

### *3.3 Mode 3 charging*

Mode 3 charging involves the direct connection of the electric vehicle to the a.c. supply network utilizing dedicated electric vehicle supply equipment. The international standard IEC 61851-1 mandates the "control pilot" device between the supply equipment and the electric vehicle, 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 deenergization of the system
- Selection of the charging rate

The control pilot is typically implemented as an extra conductor in the charging cable assembly, in addition to the phase(s), neutral, and earth conductor. This necessitates the use of special dedicated accessories.

The pilot current is sent through the loop formed control pilot conductor and the earth conductor, through a resistor in the vehicle. The current returns to the charging post through the earth conductor. When the pilot current flows correctly, the contactor in the charging post is closed and the system is energized.

When no vehicle is connected to the socket outlet, the socket is dead. Power is delivered only when the plug is correctly inserted and the earth circuit is proved to be sound.

An overview of the principle scheme is found in Figure 5. The ampacity control function is implemented in the new version of the standard 61851-1 through the shape of the control pilot signal with the duty cycle defining the current that the charging point can deliver.

The new version of the standard allows alternative ways to obtain the control pilot functionality. One

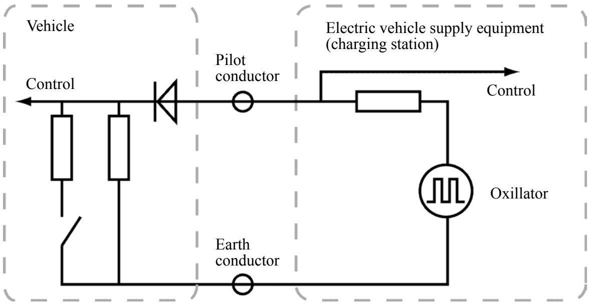


**Fig. 5** Control pilot circuit [IEC 61851-1]

example is the use of power-line communication. An interesting implementation of the latter has been developed by Electricité de France [Bleijs 2009]. The principle is illustrated in Figure 6. The control pilot signal is a common-mode signal between the phase wires and the earth conductor, using a 110 kHz carrier frequency. Filter circuits are present to avoid the unwanted transmission of data signals from the charging system to the mains, and to be compliant with relevant standards and regulations [EN50065-1].

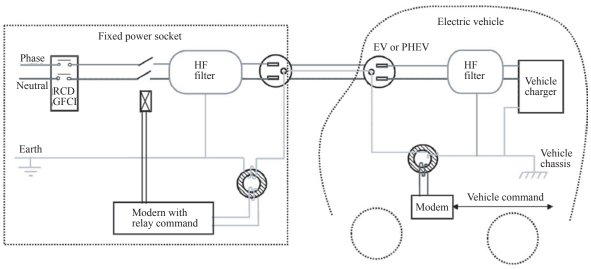


**Fig. 6** Pilot circuit with PLC communication

### *3.4 Mode 4 charging*

Mode 4 charging is defined as the indirect connection of the electric vehicle 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.

## 4. COMMUNICATION ISSUES

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, nondedicated socket outlets are used, there is no communication at all. In Mode 3, there is the control pilot communication with the added option of ampacity control; Mode 4 d.c. charging (particularly used for fast charging) will in most cases need additional communication functions to allow battery management.

The development of new concepts such as “smart grid” or “vehicle to grid” has created however the need for more advanced communication functions providing functionalities such as:

- Vehicle identification and billing
- Charge cost optimization
- Grid load optimization
- Peak-shaving functionalities (vehicle-to-grid)

The standardization of these issues is being addressed by a joint working group uniting ISO TC22 SC3 (electric equipment on road vehicles, including on-board communication systems), ISO TC22 SC21 (electric road vehicles), and IEC TC69 (electric road vehicles).

The new standard, ISO/IEC 15118, will 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.

In order to define the implementation of the communication in the lower layers, it is first necessary to analyze the real communication needs and the information to be transferred by the different “actors” involved in the charging process. These actors include physical devices such as the charging post or the vehicle controller, entities such as electricity suppliers or

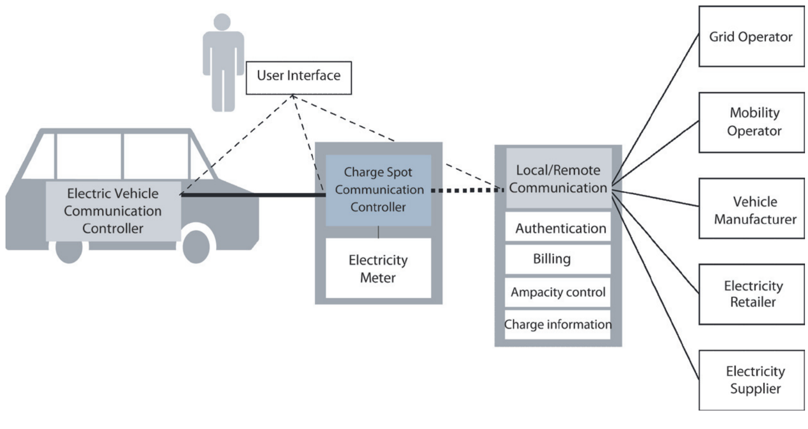


**Fig. 7** Actors involved in charging process

grid operators, and last but not least the vehicle user. An overview of actors potentially involved and the communication links between them is shown in Figure 7.

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 the system can thus become rather complex, with the danger of overstandardization lurking around the corner.

All charging processes can be contextualized in so-called "use cases," where three main categories can be discerned:

- Charging with no communication: this is the classical Mode 1 or 2 charging, also Mode 3 charging with only the basic control pilot safety functions
- Charging with minimal communication: Mode 3 charging with ampacity control to adapt to local physical limits or to perform dynamic grid optimization
- Charging with maximum communication, including automatic billing and grid control and process information

These increasing functionalities are illustrated in Figure 8.

The actual communication technique used can vary, with several solutions being experimented: RFID tags,

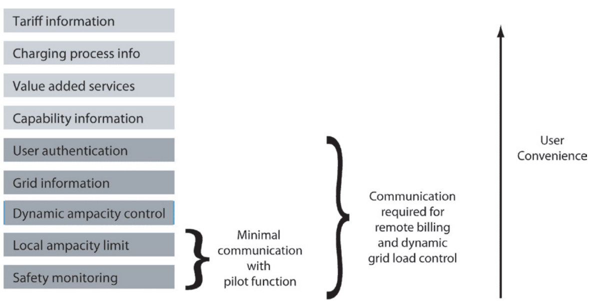


**Fig. 8** Increasing functionality

pilot conductor or powerline communications, CAN-bus, wireless (Bluetooth or ZigBee), mobile phones, etc.

The use cases are then represented by scenarios describing the sequence of events when an user charges the vehicle.

## 5. PLUGS AND SOCKETS

For Mode 1 or 2 charging, but 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 10–16 A [IEC60083]. One has to recognize however that these domestic plugs, particularly not the low-cost versions mostly used on consumer grade equipment, are not really suited for the heavy-duty operation of electric vehicle charging. This leads to a shorter lifetime of the accessories and to contact problems which may cause hazardous situations. It is thus recommended to use industrial plugs and sockets [IEC 60309-2]. These are widely used 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 IEC 60309-2 family.

The use of a physical control pilot conductor however necessitates the introduction of specific accessories for electric vehicle use. Such plugs and sockets are described in the international standard IEC 62196 "Plugs, socket-outlets, vehicle couplers and vehicle inlets – Conductive charging of electric vehicles."

Part 1 of this standard gives general functional requirements; it is based on the general standard IEC 60309-1, adapted with the requirements of IEC 61851-1.

The second part of the standard, now under preparation, proposes several types of accessories, the (proposed) designs of which are illustrated in Figure 9.

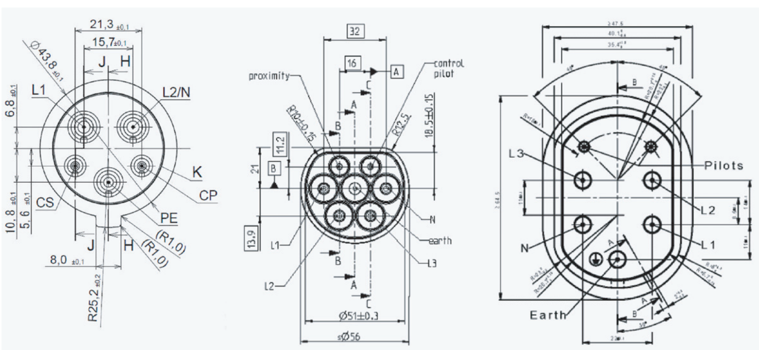


**Fig. 9** IEC 62196-2 connectors

- Type 1: a plug rated for 250 V and 32 A single phase, and two auxiliary contacts.
- Type 2: a plug rated for 400 V three-phase, and up to 63A, also with two auxiliary contacts
- Type 3: a plug rated for 400 V three phase and up to 32/63A, also with two auxiliary contacts.

Type 1 corresponds to the proposal of SAE J1772; for applications in Europe however, where three-phase power distribution is more widespread, there was a demand for three phase accessories represented by types 2 and 3. The choice between the types is not only influenced by commercial preferences but also by existing national regulations. In particular, some countries demand shutters to ensure IPXXD protection on all socket-outlets in domestic environments. Type 3 connector can accept shutters whileas Type 2 is not designed for them. The fact that in Mode 3 any socket-outlet is dead unless a vehicle is properly connected my obviate the need for shutters; for some parties, however, the non-use of shutters is considered a retrograde step in the field of safety which may create a wrong impression on the public.

## 6. CONCLUSIONS

One of the main problems facing electric vehicle standardization work has always been the collaboration between the electrotechnical world and automotive manufacturers. The electric vehicle is in fact a device which is both a road vehicle (dealt with by ISO committee) and an electrical appliance (dealt with by IEC committee), where there are substantial differences in standardization culture between the automotive and electrotechnical realms. Energy storage standardization is now focused on performance defining issues and safety, the introduction of standard geometries being a future development since the lithium technology is still evolving. Charging infrastructure standards are being defined taking into account relevant other factors such as national electric codes. The communication between the vehicle and the charging post, considering also the “smart grid” interaction is a complex issue which carries a clear risk of overstandardization which is to be avoided to come to a workable standard. Only through a positive collaboration involving relevant actors in the field will it be possible to realize unified solutions which will be a key factor in allowing the deployment of electrically propelled vehicles on a global level.

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