The Evolution of Standardisation in the Electric Vehicle World

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Abstract

The paper gives an brief overview of standardisation activities for electric and hybrid vehicles, looking back to the origins of electric vehicle standardisation and focusing on the current and foreseen developments in the field. A particular interest will be given to the genesis of standardisation activities and the perceived need for standards in the electric vehicle field. The paper reflects ongoing research performed by the author in the domain of standardisation.
Of the various fields of technology concerned with electric vehicles, standardisation is well developed and sought after in some (the most obvious example here being recharging infrastructure; the electric vehicle whilst recharging becomes in fact an electric appliance connected to the grid), and not developed or even deemed unnecessary in others (like drive train components). The reasons for these developments are historical, cultural and technological.

Keywords: standardization, infrastructure

1 Introduction

In urban traffic, due to their beneficial effect on environment, electric vehicles are an important factor for improvement of traffic and more particularly for a healthier living environment.
Standardisation has become a very important activity in this field of technology, and its necessity and usefulness are well known. However, the development of standardisation activities in the electric and hybrid vehicle field is still going on, and the activities of the standardisation committees merit a more detailed study, including the historical background of electric vehicle standards, as these do reflect the definition of policies for future developments.

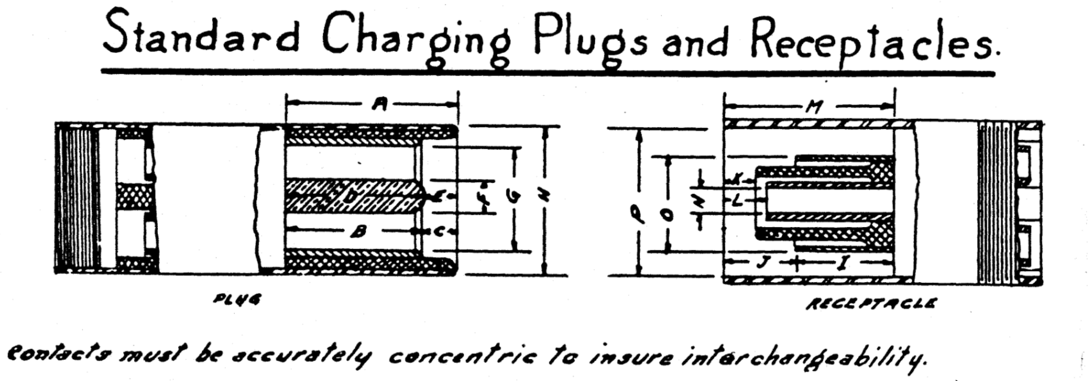
2 Historical developments

2.1 Generalities

The first great wave of electric vehicle development took place in the first years of the 20th century, and the need for standardisation was soon felt. A "standard" is defined [1] as a *document, established by consensus and approved by a recognised body, that provides, for common and repeated use, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context*. An international standard is a standard adopted by an international standardising/standards organisation and made available to the public.
The emerging electrical industry, which was new and had not to take into account a body of precedent and previous practices to follow, was really the first to take hold of the subject "standardisation" properly and to give international endorsement to a broad and comprehensive system of standards [2]. It was soon appreciated that effective standards could only be developed by competent technical bodies, as attempts for legislation and standardisation drafted by legislature often yielded unusable, inadequate or foolish specifications. In the electrical field, a large involvement in standardisation was thus taken on by electricity producers, or "central stations", as they used to be called at the time.
The International Electrotechnical Commission (IEC) was founded as early as 1906, as a result of a resolution passed at the International Electrical Congress held in St. Louis, Missouri, in 1904. The International Organisation for Standardisation, which caters for standards in the non-electrical field, was founded much later, in 1947.

2.2 Charging infrastructure standardisation

Before the advent of compact solid-state rectifiers and power electronics, battery charging equipment tended to be heavy and bulky (mains frequency transformers) and fragile (mercury arc rectifiers), and was thus mostly located off the vehicle, the latter being charged with d.c. current, what now is called “Mode 4” charging. It must also be taken into account that a large part of the electricity distribution early last century, particularly in the United States, was done under d.c. form. The charging could than take place by simply connecting the electric vehicle battery to the grid, with a regulating rheostat in series.
With the rapid increase in electric vehicles on the road, both commercial and “pleasure” types, the desirability of the adoption of a standard form of charging plug became more and more apparent. Electric vehicle users were in fact using their vehicles also for missions beyond their immediate surroundings, and charging away from the home garage was required. The need for infrastructure (specific plugs) became apparent particularly if the vehicle was being used by a non-specialist; to the practical electrician in fact, the absence of a proper charging plug offered no difficulty that could be easily overcome with a few pieces of wire and a few moments work. The average car user however knew little about wiring practices, and in order to guarantee the success of electric vehicles, there must be plenty of charging stations which are equipped with suitable charging plugs.
The first steps towards standardisation in this field came early in the past century [3]. At that time, about eight different patterns of plugs were in use. The concentric form had been adopted by nearly all builders of commercial vehicles, had been approved by the board of fire underwriters in some large cities.
The standardisation of charging plugs and receptacles was proposed through the adoption of a concentric design in two sizes: one aimed at heavy commercial vehicles, the other one to pleasure vehicles. Its structure is illustrated in figure 1, and was adopted as a standard in 1912. [4]
The idea of a standardisation committee (called “Committee on Design and Adoption of an Universal Charging Plug”) appointed by the Electric Vehicle Association of America was supported by all large electric vehicle manufacturers of the time. The design obtained was acceptable to at least 95% of the manufacturers, although its price was higher than the previous proprietary designs. Manufacturers were thus clearly willing to pay something for standardisation [5].



Capacity	A	B	C	D	E	F	G	H	I	J	K	L	M	Machine N	Spring N	Machine O	Spring O	P
50 AMP	1 13/16	1 9/16	3/8	1 5/8	5/16	.373 .375	1.125 1.127	1.725	1 1/8	7/8	3/8	3/8	2	.375 .377	.360 .365	1.123 1.125	1.136 1.140	1 3/4
150 AMP	2 3/8	1 9/16	13/16	2 1/16	5/16	.435 .437	1.406 1.408	2.100	1 13/32	1 5/16	5/16	7/16	2 13/32	.437 .439	.422 .427	1.404 1.406	1.416 1.421	2 1/8

Figure 1: Standard concentric charging plug accepted by the Electric Vehicle Association of America [6]

These early developments clearly highlight the perception of the need of standardisation, a need which is still there today, even when considering the technology leap associated with the introduction of power electronics.

2.3 Battery voltage standardisation

The need for standardisation was also felt in the field of battery voltage, expressed as the number of cells of the battery. The reasons behind this were stated in the following paragraph, which we quote here because of its clarity and style.

> *"Now that the Electric Vehicle is at least "coming into its own", the standardization of the most essential parts becomes almost a necessity.*
>
> *Especially this is true of the number of cells used:*
>
> *1st. Because the nation-wide interest shown by all the central stations. It cannot be expected that a majority of central stations will go to the expense of providing facilities for charging at a great variety of voltages. Furthermore, the risk and trouble of changing or adjusting the charging rate will not prove at all attractive, considering the small revenue derived, and the class of help employed, where a station is called on to do a general charging business.*
>
> *2nd. That proper facilities of charging may be had at all public garages and the necessity of making it easy for these stations to obtain standardized charging equipment. It is to the central station that we must largely look to foster this industry and make the purchase and use of electric vehicle popular; therefore, we must seek to make their technical problem easy and the work attractive. Nothing will contribute more to this end than the adoption of standards of equipment and service wherever possible.*
>
> *3rd. That a vehicle usually charged in a private garage while "en tour" may be charged at any other garage or central station."* [7]

The early technological development of the electric vehicle had been characterised by a gradual rise in battery voltage, the higher voltages allowing for lower currents and thus for lower copper losses and higher efficiency, particularly in heavy load conditions.
At the Electric Vehicle Association of America meeting mentioned in [7], the following values of standardised voltages were proposed:

Table 1: Standardised battery voltage

Number of cells	Rated voltage	Max. Charging voltage required
Lead batteries		
30	60	77,5
40	80	102
42	84	107
Alkaline batteries		
40	48	72
60	72	108
62	74,4	112

These proposals would allow the adoption of two charging voltages with a small amount of regulating resistance (it is worth to note the accordance to the then common 110 V d.c. distribution voltage), simplifying matters considerably. This aspect of simplification is one of the main benefits of standardisation activities. The standardisation work was effective: by 1912-13 nearly all vehicles on the American market were equipped with batteries so that the charging voltage was from 78 V on the smaller pleasure or passenger cars to 110 V on the various commercial vehicles and the larger types of pleasure or passenger cars [8]. The standardisation of charging plugs and battery voltages thus became an effective achievement of the (first) Electric Vehicle Association of America [9].

2.4 Vehicle speed standardisation

Standardisation activities were also performed regarding the speed of electric vehicles. The reasons for this work were various. First of all vehicle safety was concerned, this was treated with the spirit of the time which was not yet affected by political correctness, as can be witnessed from the following quotation:

> *"But when you stop to consider that one of these glass-enclosed vehicles weighs nearly one ton and a half, with passengers, and is capable in some cases of making 25 miles on good roads, do you not think that the speed is too high for a vehicle to be properly controlled by a woman or a child? Twenty miles an hour I consider very fast, yet the braking strain is 56 per cent. greater at 25 miles than at 20 miles."* [10]

Another aspect however which provoked the interest in speed standardisation was the energy consumption. It was in fact observed that energy consumption of electric vehicles increased largely with higher speeds, the factors acting here being identified as friction and wind resistance (windage). On the other hand, customers were demanding faster vehicle, also influenced by the performance of gasoline-powered sports cars. The high speeds however led to excessive consumption values and thus lower range of the vehicles, and, according to the electricity producers or central station men, a standard maximum speed for electric vehicles was desirable. Their position is typically illustrated in the following quotation:

> *"I am very glad to learn that the standardization of speed as indicated here is the best for certain types to gain the highest efficiency in their operation. Some of the speakers have stated that we have got to meet the desires of our purchasers. I think in this, as in a great many other things, it is best to educate the public as to what is best for them, and not always to give them what they want."* [11]

Due to differences in opinion between vehicle manufacturers and electricity producers, and due to the growing competition, this proposed standardisation of speed for electric vehicles was never concretised however [12].

3 Current developments

3.1 Generalities

After its first "golden age" in the first quarter of the 20th century, the electric vehicle suffered from the large development of the thermal vehicle and became retracted to niche markets like industrial vehicles. Standardisation efforts in this field continued, and for components such as batteries dimensional standards were drafted [13], so that the availability of standardised components allowed for an more efficient logistic implementation and an opening of the battery market. This standardisation allows the user of an industrial electric vehicle (e.g. fork lift truck) to choose between many different suppliers for his traction battery, thus enabling an element of competition which makes the product become cheaper than when the user would depend on a single supplier.

The new age of the electric road vehicle came into being during the last quarter of the 20th century, with the availability of power electronics allowing an unprecedented development of electric vehicle technology all over the world, up to the point where only market forces impede the breakthrough of the electric vehicle as a clean and efficient mode of transport.

Legislation and the awareness of people have created a pressure for zero emission vehicles, which is driving the requirements for electric vehicle standards. These are focused particularly on component interfacing, safety, definitions and methods of measurements. The technologies involved in electric vehicles are moving very quickly, particularly in the field of batteries, power electronics and drive systems. Generic standards to assure safety of persons, to measure performances and to ensure compatibility will continue to be developed as the technology advances.

3.2 Standardisation bodies active in the field

With standardisation of the electric road vehicle becoming an key issue, the question arises which body would be responsible for these 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:

- on one hand, the electric vehicle is a road vehicle, the standardisation competence for which is the province of ISO;
- on the other hand, the electric vehicle is a piece of electrical equipment, the standardisation competence for which falls under the wings of the IEC.

This difference is even more stressed by the constitution of the technical committees working groups in the two organisations: in ISO, there is a strong input from vehicle manufacturers, whileas in IEC many of the delegated experts are electricians. Furthermore, there is a fundamentally different approach taken towards the concept of standardisation in the automotive and the Electrotechnical world. There is a different "standard culture", the origin of which can be traced back to historical reasons:

- In the car manufacturing world, standardisation is not so widespread: every manufacturer desires to develop his own technical solutions, which in fact make his product unique. Standardisation for road vehicles is limited to issues covered by regulations (safety, environmental impact, energy consumption measurements), and to areas where interchangeability of components is important. For components like combustion engines for example there are very few standards. In the automotive industry in fact, most manufacturers were (and to a certain extent still are) responsible for the manufacturing of all components (e.g. the combustion engine) for a certain vehicle. This made the need for overall standardisation much less stringent. Also, the individual customer is unlikely to require strict compliance to standards; safety or emission regulations however may be enforced by governments.
- In the electric world, there is a much longer tradition for standardisation, as cited above, and a stronger tendency to standardise all and everything; furthermore, standards are more looked upon as being legally binding documents. Electric motors are covered by extensive standards covering their construction and testing. Even the colour code of wires is standardised (e.g. green and yellow for the protective or earth conductor). In the Electrotechnical industry in fact, the role of specialist component manufacturers acting as suppliers to equipment manufacturers has always had a strong tradition. Furthermore, the customers of the Electrotechnical industry are more likely to be powerful corporations (e.g. railway companies) who tend to enforce very strict specifications on the equipment they order or purchase, hence the need for more elaborate standards to ensure the compliance of the equipment.

The current evolution of the electric vehicle standardisation work has clearly reflected this dual-sided approach.

The first new efforts in standardisation saw the light. IEC produced some technical reports (not actually standards) about electric vehicle components [14] in 1984. These documents, developed from an electrician’s point of view, had only a limited impact and have known no revisions.
The standardisation work group in charge of motors and controllers for electric vehicles, IEC TC69 WG2, has been dormant for several years, since a large number of car manufacturers, according to their traditions, deem this kind of standardisation work unnecessary.
A joint steering group encompassing delegates from both ISO and IEC has been set up to clarify the division of labour between the two main standardisation bodies.
Its approach of the matter can be summarised as follows:

- Aspects related to the vehicle itself are covered by ISO

- Aspects related to the vehicle coupled to the electrical network (such as charging infrastructure, EMC issues during charging and the like), as well as purely electrical aspects of components such as batteries are covered by IEC

On a European level, a similar structure exists with CENELEC catering for electrotechnical standards and CEN for general standards. The European standards developed here are mostly endorsements of international IEC and ISO standards.

3.3 The influence of new technological developments

There are however a number of overlapping areas which are not fully covered by this division., such as the connection of the traction equipment to the electric network.

Before the availability of reliable and affordable power electronics, vehicles were driven by series d.c. motors, speed control being achieved by resistive controllers. The series d.c. motor is in fact well suited for traction applications and can be married easily to the d.c. source which is the battery.

This drive train configuration remained virtually unchanged for over half a century. From the 1960’s on, the emergence of electronic switching devices such as thyristors allowed for smooth control and enhanced energy efficiency. The shunt d.c. motor became popular for its ability to independently control speed and armature current, which facilitates field weakening and regenerative braking. Power electronics thus shaped the way for the renaissance of the electric vehicle in the last few decades.

The evolution in power electronics showed steady progress, with new components (GTO, Mosfet, IGBT) and new control techniques (microprocessors) which introduced the use of a.c. motors (particularly asynchronous ones) in variable-speed applications including traction. Asynchronous motors are cheaper to manufacture, require less maintenance and are more sturdy then d.c. ones.

The typical a.c. driven electric vehicle contains an inverter which transforms the d.c. from the battery in a.c. for the traction motor. During regenerative braking, the motor functions as generator, feeding a.c. to the inverter, which rectifies it to recharge the battery. The current levels during this braking can be high, up to the maximum acceleration current, corresponding to the full power of the vehicle.

This recharging capability of the inverter could also be used however during battery charging from an external a.c. supply, at high power levels. This leads to the possibility of fast charging, with a high-power a.c. connection, which represents a much lighter infrastructure than the off-board fast charging stations which supply the vehicle with d.c.

Furthermore, such structure offers the opportunity of supply network management, using the batteries of electric vehicles connected to the network as peak shaving units, feeding a.c. in the network through the inverter .

The situation described above for charging presents the following features which differ it from the “ordinary” charging procedure of batteries:

- The charging of the battery is done through a vehicle component (the inverter) which also performs other functions in traction, and not through a dedicated (on or off board) charger.
- Since the inverter is not necessarily (and in most cases is actually not) providing galvanic isolation between the d.c. “motor” side and the a.c. “battery” side, the vehicle traction circuits, including the battery, are directly connected to the a.c. supply network. This is a fundamental difference with conventional chargers, which in virtually all cases are isolated between input and output through the use of a (low or high frequency) transformer. This may have an impact on equipment safety.
- A bi-directional power flow may exist between the vehicle and the supply network.

The inverter and battery, being connected to the network, become an “electric device”. There is a clear overlap here between the activities traditionally attributed to IEC and those catered for by ISO.

The concept of “electric device” makes it desirable to provide standardisation, in order to address the following issues:

- Safety: protection of personnel
- Interference with the network, including EMC (particularly in the case where a bi-directional energy flow between the vehicle and the network is foreseen)
- Difference between stand-alone component performance and “on-vehicle” performance.

New standards on this issue, which have now been proposed as New Work Item (to be performed by IEC TC69 WG2), although clearly falling in the province of IEC, must be an answer to the needs of ISO since they refer to electric vehicle components and thus to the vehicle itself. Due to the close interweaving of vehicle-related aspects and equipment-related aspect, and reflecting the ideas of the agreed division of labour IEC/ISO, close collaboration with ISO will have to be sought on relevant matters .
To be acceptable to automotive manufacturers, the new document should not be too restrictive in imposing constructional limitations, but rather give a support for recommended practices.

3.4 Overview of international standardisation work going on

The past few years international standardisation bodies, both on IEC and ISO level, have been very active in the field of electric vehicle standardisation. The main documents issued and under preparation can be summarised as follows:

3.4.1 IEC TC69

The main activities of the IEC have been connected with charging and infrastructure issues. An earlier document which had been developed and which saw its last revision in 1997 [15] has now been superseded with a comprehensive set of standards covering all aspects of electric vehicle charging. The documents relative to the conductive charging have been published in 2001, following several years' work of the Working Group 4 of TC69. These documents, all under standard number IEC 61851, are structured as follows:

- Part 1: General requirements [16] which applies to equipment for charging electric road vehicles at standard a.c. supply voltages up to 690 V and d.c. voltages up to 1000 V, and for providing electrical power for any additional services on the vehicle if required when connected to the supply network.
- Part 21: Electric vehicle requirements [17], which together with part 1 gives the electric vehicle requirements for conductive connection to a.c. or d.c. supply when the electric vehicle is connected to the supply network.
- Part 22: AC Charging station requirements [18], which together with part 1 gives the requirements for a.c. electric vehicle charging stations for conductive connection to an electric vehicle.

For inductive charging, the work is still going on, the relevant document, IEC 61980, is circulated as a committee draft. Its structure is similar to IEC 61851 and it consists of the following parts:

- Part 1: General requirements
- Part 2: Manual connection system using a paddle

3.4.2 IEC SC23H

This committee deals with industrial plugs and sockets. Its Working Group 6 is specifically in charge of plugs and socket-outlets for electrical vehicles. The specific needs of the electric vehicle,and the evolution of charging techniques have led to the development on IEC 62196 “Plugs, socket-outlets, vehicle couplers and vehicle inlets – Conductive charging of electric vehicles”, with specifications based on the well-proven IEC 60309-1 standard [19] on industrial plugs and sockets.

3.4.3 ISO TC22 SC 21

The standardisation work inside ISO deals with issues relative to the vehicle itself. In line with the tradition of automotive manufacturers, the standards are not describing vehicle or component details (such standards would be deemed too restrictive), but are concentrating instead on safety and performance measurements. The standard ISO 8715 describing the road operating characteristics for electric road vehicles was published in 2001 [20]. It determines on-road performance data for purely electrically powered cars and light commercial vehicles, such as maximum speed, maximum 30-minute speed, acceleration and climbing ability.

Furthermore, the following document are at the stage of draft international standards:

- ISO/DIS 6469-1: Electric road vehicles – Safety specifications – Part 1: On-board energy storage. This document specifies the technical safety requirements for on-board electrochemical batteries as used to power electric vehicles (cars and light commercial vehicles) from the standpoint of protecting passengers and the vehicle surroundings.
- ISO/DIS 6469-2: Electric road vehicles – Safety specifications – Part 2: Functional safety means and protection against failures. This document specifies the technical safety requirements for electric vehicles in respect of functional safety precautions and measures associated with the electric power plant.
- ISO/DIS 6469-3: Electric road vehicles – Safety specifications – Part 3: Protection of persons against electric hazards. This document specifies the technical safety requirements for electric vehicles for the protection of people from electrical hazards when the vehicle is not connected to an extrnal power supply.
- ISO/DIS 8713: Electric road vehicles – Terminology. This document collates terms and definitions for electric vehicles which are used in the individual standards.
- ISO/DIS 8714: Electric road vehicles – Reference energy consumption and range – Test procedures for passenger cars and light commercial vehicles. This document specifies methods to determine the energy consumption and range of purely electrically powered cars and light commercial vehicles.

The ISO committee has adopted new subjects for standardisation, such as:

- Safety related requirements for fuel cell vehicles
- Energy consumption and range of hybrid-electric vehicles
- Terminology and definitions for fuel cell and hybrid-electric vehicles

4 Conclusions

Standardisation work on electric vehicles is an activity performed by several concerned parties in the field: automotive and component manufacturers, energy suppliers, and others like user groups or government agencies. On one hand, the combined expertise of these partners will allow the writing of quality standards which are to become useful working documents for all those in the trade; on the other hand, each of them has their particular social or business interests which may influence their viewpoint on standardisation an which will ultimately define the agenda of the standardisation committees. These aspects can be found back as well as in the first historic development of standardisation as in today’s activities in the field.

The key areas where standardisation shows its benefits are now all represented concerning the electric vehicle:

- Safety standards for protection of personnel
- Performance measurement standards
- Compatibility standards, which mainly concern the vehicle infrastructure. These standards are essential to allow the development of a large-scale market for the electric vehicle.

The activities of all the committees active in the field will lead to a structured set of documents describing the different aspects of the electric vehicle technology. However, taking into account the rapid evolution of the technology in the field, these documents are in no case to be considered as definitive, and they will be in constant evolution and revision. To this effect, standardisation bodies have defined maintenance schedules in order to keep standards and documents up-to-date.

However useful the definition of standards may be, one should take into account the danger of over-standardisation or the drafting of standards just for the sake of the standard without a technological necessity behind. On one hand, a too narrow definition of a standard may reflect a momentary state-of-the-art, which is due to change anyway, so that strict adherence to it may impede further technological evolution. On the other hand, the existence of “frivolous” standards may incur extra and unnecessary costs for performing conformity tests.
Also in the case where standard documents are forced into becoming regulations and/or directives, which are legally binding documents, a more generic approach in drafting the standard may be desirable. However, documents relative to electric vehicles (battery-electric, hybrid-electric and fuel cell vehicles) must always take into account the specific characteristics of these vehicles, and not merely mimic existing specifications for internal-combustion engined vehicles.
Safety of the vehicle and of its associated infrastructure may of course not be compromised, and safety standards will be particularly significant in the legislative and regulation fields.

There clearly remains a key task in the field for the standardisation bodies, which, in their tradition of voluntary mutual collaboration in an atmosphere of consensus, have a solid contribution to the worldwide acceptance of the electric vehicle.

This way, the electric vehicle standardisation work creates a unique opportunity to overcome differences between nations, between economic actors or between business competitors, in order continue the to electric way together towards a better future for humanity.

Note: The research project in which this paper frames is being continued to encompass a comprehensive analysis of electric vehicle standardisation activities on a global level during the past century and of future evolutions in the field.

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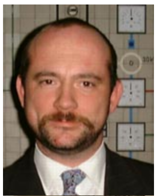

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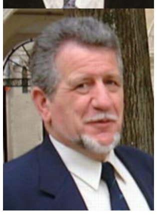

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