Raising Electric Vehicle Standards Throughout A Century: Principal Trends And Evolutions

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Abstract

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. The emergence of the electrically driven vehicle, either as a completely new technology or as a new field of application of existing technologies, represents particular challenges in the field of standardization. It encompasses in fact various domains of technology such as electric traction motors, power converters, storage batteries, battery chargers and general automotive technologies, each of which have their own traditions and constraints in the field of standardization.

Specific electric vehicle standardization has a long history: the first real "electric vehicle standard", which dealt with charging plugs, being published in 1912. Since then, work has been performed by various agencies on a diversity of topics. The paper will give an overview of this evolution throughout the century, defining the main evolution lines that have been remarkably constant during the years.

At first, the main areas where standardization has been performed will be drawn: with the exception of general topics like terminology, standardization work can be mainly divided in three major areas:

- Dimensional standards, like plugs, sockets and battery sizes, which have been the first to emerge, their introduction being beneficial in practice;
- Safety standards, where the interaction between standardization and governmental legislation has to be taken into account;
- Performance standards, which allow to compare products to eachother and which have gained particular interest for energetical and environmental assessment

Furthermore, interesting viewpoints can be derived from considering the interaction between actors in the field. Electric vehicle standardization started from within the electric vehicle community, but quickly became absorbed by the larger national, regional and international standardization bodies. The very nature of the electric vehicle, which is both a "road vehicle" and an "electric appliance", created particular problems as to the responsibility for standardization work, as these main subject are treated, for historical reasons, by different bodies which have each their own approach and "standardization culture".

The paper, which is the result of a PhD project [1], will provide interesting insights in the process of electric vehicle standardization, which in itself provides a reflection of the economical and societal developments surrounding electric vehicles.

Keywords: standardization

1 The early years: the emergence of the electric vehicle in the beginning of the 20th century

Standardization activities specific to electric vehicles took off in the first decades of the 20th century, particularly in the United States, under the impulse of the (then) Electric Vehicle Association of America. The first standard to be published concerned a standard charging plug, other areas of activity concerned the standardization of battery voltage, battery jars, vehicle speed and motor ratings. This paragraph will give an overview of the result of this work.

1.1 Parties involved

The standardization work concerning electric vehicles was initially taken on by organizations like EVAA whose main aim was to promote the electric vehicle.
It was shifted quite soon to specialist standardization bodies like SAE; this situation has remained up to this day, where electric vehicle promotion organizations, like the EDTA, or AVERE, are not drafting standards themselves; although many of their members actively perform standardization work, they do so in the framework of an organization like IEC or ISO which has the international authority for the redaction of standards.
The JEVA in Japan is a notable exception to this case however.

Most of the actual standards of the period concerned were taken up by the SAE, which profiled itself as the main standardization body in the field. Contacts with other bodies such as the AIEE were established in a spirit of co-operation; there was no sign yet of the "competition" between different organizations which would come into play later.

1.2 Impact of standardization

1.2.1 Successful standards

Some of the standards developed can be designated as successful, in the sense that they saw a large acceptance in the market and did continue to be supported further in time.
A first example are the dimensional standards of charging plugs, which saw continued application in the electric vehicle field. The subject of this standardization continues to generate interest, as work on plugs and connectors is in progress up to this day.

The standardization of traction battery jars and trays found also a wide application. These standards allowed several manufacturers to propose interchangeable products, thus enhancing competitiveness and ultimately lowering the cost for the end user.
Voltage standards found their application out of practical and cost reasons; it should be said however that standard voltages also became imposed indirectly due to the introduction of standardized battery trays, thus fixing the number of cells in use.

1.2.2 The question of ratings

The definition of ratings for electric vehicle motors took into account the specific operating conditions of electric vehicles, which are differing from industrial electric motors. The application of electrotechnical ratings on electric road vehicle will continue to be a difficult issue however.

Speed and mileage ratings were the subject of considerable discussions, as it is difficult to define a rating of speed or mileage which is coherent to real use of the vehicle, the energy consumption of an electric vehicle being strongly dependent on the type of mission. The definition of such rating and of the test cycles for it will remain a constant discussion point up to the now, as will be seen below.

1.2.3 Botched standards

The attempt to standardize speed was botched. This standardization, which in practice would mean the definition of a standard maximum speed, was not feasible facing the rush for high speeds, fueled by the "race" aspects of the gasoline vehicles. This speed argument continues to counter the electric vehicle up to this day, even if it is, particularly in urban conditions, void of much rationality.
Standardization of tires also proved difficult, and the committees did not come out of it or manage to come to an agreement.

2 The intermediate period and the emergence of the industrial electric vehicle

After 1920, the electric road vehicle receded into niche applications, such as industrial vehicles. The development of the electric vehicle into the industrial vehicle field has given rise to extensive standardization work being performed in the field. The main characteristics can be summarized as follows:

Standards were obviously developed in the fields where these are most useful for rationalization, simplification and cost reduction, such as standard connectors and standard batteries; for the latter, the number of sizes used has been reduced to a series simple enough to be rational but extended enough to cater for all industrial vehicle needs.
Other standards, like the standard on voltage, have led to an extension of the number of standardized values, reflecting the evolution of the technology in the field.

There is also the emergence of a new type of standard: the safety standard, which states a number of requirements for the considered equipment in order to be used safely.
These standards go beyond the domain of mere industrial standardization, as they become embedded in legislation and regulation.
This can be seen for example when considering the influence of EU directives (legislation) on en standards (standardization).

3 The developments of electric vehicle standards towards the end of the 20th century

The last quarter of the past century saw a considerable growth in interest for the electrically driven vehicle, which can be ascribed both to technological and societal reasons. Research and development work on electric vehicles took place on a world-wide scale, and standardization work soon followed, being performed both on national, regional and international scale. This process continues up to this day, taking into account the emergence of new technologies such as hybrids and fuel cells. The study of the evolutions in the field has permitted to make some general statements on the evolution of the standardization in the field.

3.1 Evolution of standards development: general findings

From the first attempts to standardize plugs, voltage levels and batteries, standards have been developed, extending on the same subjects and embracing new topics to keep abreast with technological and societal evolutions. Throughout this evolution, the fundamentals of standardization however have remained remarkably constant. The main issues encountered in the course of this work give rise to the following assessments which allow to appraise the evolution in the field and to state our recommendations based on the experience gained from this work:

- Standardization work, however interesting it may be, will not and should not be performed for the sake of standardization only. There must be a clear demand perceived by the stakeholders. Standardization on a certain subject will thus reflect the underlying economic activity in the concerned sector.
  We have seen that electric road vehicle standardization work vanished after the First World War, to be revived only with the renewed interest in electric vehicles in the 1970s. The activity level during the following years went up and down however, according to the interest of the moment in electric vehicles, as has been seen for example with the activity level of ISO TC21 SC22. The current state of IEC TC69, which has been virtually dormant during the last four years, its last plenary meeting being held in 1999, can be explained as well by the decreased interest from vehicle manufacturers for the battery-electric road vehicle with the advent of hybrids and fuel cells. As will be seen below, there are however interesting future work items left for this committee.

- Standardization does serve an useful purpose, but it should be introduced wisely and appropriately. The drafting of standards on non-critical subjects, such as the noise emissions of battery chargers, or the definition of excessively demanding requirements may hamper development and deployment of a technology rather than assist it.
  Such overstandardization can be caused by apprehension when confronted with a new and unknown technology, but it can also be implemented deliberately in an evil attempt to thwart new developments.

- The main enemies of effective standards are other standards that are contradictory. They bring confusion for the user and undermine the authority of the standardization bodies and eventually of standardization itself.
  The need for close collaboration between standardization bodies remains a paramount issue on all levels.

- On the sectoral level, such as between IEC and ISO, the division of work between standardization bodies shall be performed on the basis of collaboration and not of competition, taking into account the specific know-how existing in the respective committees. The mutual understanding of the dissimilar approach that different sectors may take towards standardization and technological development, the recognition of reciprocal work and the multidisciplinary constitution of standardization committees will prove to be essential elements in ensuring such a collaboration to be effective.
  The establishment of a single body in charge of international standardization (i.e. merging IEC and ISO, and cf. the proposals to merge CEN and CENELEC in Europe) could provide a setting in which these collaboration issues would be resolved more smoothly. Such a merger doesn't seem very likely to occur in the short term though, due to the

firmly established traditions in both organisations and due to the fact that they represent different industrial sectors with their own spheres of interest.
The evolution of technology however, with electric and electronic sub-assemblies being integrated in virtually every type of product, will lead to a further intertwining of electrotechnics within other fields of technology, thus posing further challenges to the organisation of standardization activities, which necessitate an effective policy of collaboration and liaison between the committees involved.
The standardization landscape that has developed around the fuel cell constitutes a good example of a collaboration scheme aiming at bringing out the best in every committee involved and allowing for the most efficient standardization work.

- On the regional level, standardization will have to take into account differences that exist due to historical reasons, such as the organization of electricity distribution in various countries, as well as local traditions that are reflected in standardization and regulation.
  It is clear however that the endorsement of international standards on regional and national level is to be preferred wherever possible; the drafting of such international standards which can be accepted worldwide is dependent on the global participation in the international committees. A good example of such a standard is the ISO 8714, which defines a common measurement procedure that can applied globally, while proposing specific speed cycles for each continent, reflecting local conditions and regulations.
  The adoption of an international standard on a global scale does not imply the imposition of a bland uniformity; on the contrary, it can highlight richness and diversity by promoting intercultural exchanges.

- The constitution of standardization committees shall also reflect the variety of interested parties: manufacturers, suppliers and users. A balance between these partners is necessary to ensure that the standard reflects all interests concerned and becomes a document of global societal value, rather than a bespoke document imposed by a single group to serve its own benefits.
  When considering the present constitution of the standardization committees however, it becomes clear that nearly only manufacturers are present The personal participation of the author in standardization work, who represented electric vehicle users through the association CITELEC, and who also reflected an academic research point of view through the VUB, has been a prime occasion to witness the leading position of manufacturers and the need to balance the presence of different interest groups in the committees.
  The active participation in the work of an international standardization committee constitutes however a considerable investment in time and money, which may represent a heavy burden for actors like SMEs, public bodies, research institutions or user organisations. A balanced constitution of the committees will thus necessitate the access to adequate funds to support participation by these parties. The value of an investment in standardization work should not be underestimated since its impact on society as a whole.
  For countries not having a manufacturing base, participation in international standardization remains interesting to have an input in the standards they will adopt as users and consumers (particularly in the case of European standards which are mandatorily converted to national standards), and a support to allow participating in, or at least actively following up, the work of the committees seems fully justified.
  The balanced constitution of standards committees is a statutory requirement in a number of standardization bodies such as the ASTM, in order to avoid that the standardization process is dominated by manufacturers only.

- National committees active in international standardization will be likely to push forward standpoints that favour the interests of their own economy. This may lead one one hand to the support of specific solutions as an international standard (such as the US paddle-type inductive charger), or to the holding back of standardization work when the own economy is not deemed ready for it. In order to avoid the standardization process to be dominated by the largest and strongest economies only, the democratic voting process ("one member - one vote") that always has been the main characteristic of international IEC and ISO standardization is a key element that should be retained.

- The consensus model, which has been the keystone of standardization since its early years, shall remain the preferred path to the approval of standards. It is the best way to ensure that all voices which have something to say can be heard and that all stakeholders in the standardization process can participate on an equal footing. The main drawback of the consensus model however is that much more time may be needed to align diverging opinions and to agree on a common solution, which will always be a compromise solution. The history of IEC TC69 WG4, where lingering discussions over a basic notion such as the definition of charging modes have kept the working group occupied during several multi-day meetings, is a typical illustration of this phenomenon. Although reaching a consensus may be more time-consuming, particularly in an international standardization committee with members from all over the world, the end result will be more acceptable for everyone: when a standard is being enforced by one party, it is not necessarily the appropriate solution for other parties concerned.
  The concept of other methodologies for standards development, for example the introduction of qualified majority voting at an early stage of the standardization process, should be carefully considered to know whether the benefits outweigh the drawbacks.

- Certain areas of society tend to be more and more controlled by government-issued regulations. This is particularly the case concerning for example safety issues. However, as much now as one century ago, as stated above, standardization drafted by legislature may yield "unusable, inadequate or foolish specifications", and standards should be developed by experts who are competent in the matter, and be based on technical knowledge rather than political viewpoints.
  The "New Approach", where legislation defines a basic set of essential requirements, with the technical details being covered in harmonized standards drafted by standardization bodies, is a good example of the complementarity of regulation and standardization, and it would be commendable to extend the implementation of this principle to areas where it is not yet implemented such as road vehicles. This will help to eliminate the confusion that can be caused by the discrepancy which in some fields exists between standards and regulatory documents such as ECE regulations. A "New Approach" in the field would displace the technical specifications in ECE regulations by references to European standards. This evolution, however desirable it may seem, will however necessitate a difficult political decision process, since the ECE regulations emanate from the UN and are thus beyond the mere jurisdiction of the EU.
  Furthermore, a "New Approach" can help to avoid the restriction of technological development through obsolete technical specifications enshrined in legislation on one hand, and through overspecification by overzealous legislators on the other hand.
  The voluntary character of standards adopted by consensus remains a vital element of personal and societal freedom which is the foundation of scientific, technological and social progress.

- Standardization bodies should improve the knowledge of "standardization" and its backgrounds among the general public and among training and teaching bodies such as engineering schools on different levels. International standards and their impact are rarely known and understood. A notorious example is the ISO 9000 quality management standard, which is often misunderstood as a product quality standard, also due to its publicitary use by corporations.
  A further responsibility lies with the press, who systematically but erroneously uses the word "standard" or "norm" to refer to legislative documents such as eu directives and the like, thus misleading the public and creating confusion about the true nature of standardization. The word "standard" should only be used for documents emanating from proper standardization committees (IEC, ISO, CENELEC, CEN, etc.).

4 Where do we go from here?

4.1 Introduction

During the last decennium, the committees active on electric vehicles have made impressive accomplishments, with standardization work being performed on both international and regional levels, and a comprehensive array of standards being published, concerning both battery-electric, hybrid and fuel cell vehicles.
The study of the evolution of these activities as made in the framework of this thesis allows to make a critical appraisal of the work done and to identify the areas where we perceive problems that are still to be resolved.

4.2 The battery-electric vehicle

For the battery-electric vehicle, for both road and industrial applications, major issues have now been covered by standards.
A number of issues are still outstanding however and merit further work:

- The electric drive train, consisting of motor and controller, does not benefit from a up-to-date standard to rely on. The evolution of technology in the field of power electronics, the influence of power electronics on electric motor design, and the potential of direct interaction between the drive train and the electric distribution network make the availability of such a standard desirable however. It is thus considered essential that the activities of IEC TC69 WG2 (which is convened by the author) could resume, in order to prepare a standard describing all relevant aspects of the on-board power equipment, including safety, emc issues and ratings, which would be useful to both vehicle manufacturers and component suppliers for electrically driven vehicles, including battery-electric, hybrid and fuel cell vehicles.
  To this effect, IEC TC69 and the IEC/ISO Joint Steering Group should resume their activities in the field, and convene a multidisciplinary working group consisting of both representatives from the automotive and electrotechnical industries in order to tackle this highly interesting issue.

- An inclusive set of conductive charging infrastructure standards have been published. There is not yet a common ground however regarding the physical layout of the

connector interface. The "universal" interfaces as defined in IEC 61851-1suit in principle all requirements, but it can be stated that they are quite complicated to see practical widespread use.
As for the standardization of plugs and sockets, progress has been made on regional (CENELEC) level, where it can be deplored however that some national committees have put forward a proprietary national solution, thus letting pass the chance to come to an international standard of intermateable accessories. The demand for an international standard solution is clearly present from an user's point of view, as has been made clear for example in the study of charging infrastructures performed by the Vrije Universiteit Brussel for the Brussels Capital Region.
The standardization of the vehicle inlets is still pending, which can also be ascribed to the fact that this issue is dealt with by a different (CEN) committee. This issue clearly needs the establishement of a collaboration between CEN TC301 WG4 and CENELEC TC69X WG3 on the matter.

- Concerning inductive charging, the low commercial interest in the field to-day is unlikely to promote standardization activities. The IEC 61980 inductive charging standard, which is now lingering in a CD stage, will most probably be abandoned, making all the work devoted to it a vain effort; such work which eventually proves to be useless is the sad fate of standardization committees facing a change in technologies favoured by the market and preferred by vehicle manufacturers.
  One can state however that the principle of inductive connection to the mains continues to be a preferable solution for those applications where this connection has to be established in a systematic and repetitive way, such as in opportunity charging for captive fleet operations like buses, taxis, goods delivery vans or car sharing vehicles, where the availability of an automatic inductive connection will offer an unprecedented safety and user-friendliness while eliminating handling as well as wear and tear problems.

- On-board chargers, which are now not described by standards, nevertheless present a number of issues, such as energy efficiency measurement, that would merit further work. The nature of the charger as "on-board power equipment" and its possible integration with the drive train equipment implies that this should be a work item for IEC TC69 WG2, with of course the necessary collaboration with IEC TC69 WG4 on infrastructure issues and ISO TC22 SC21 on infrastructure issues.

- Battery performance standards (the IEC 61982 series) have been specifically drafted for the battery-electric vehicle application - these standards can be considered as successful developments of their kind and will be of use to both battery and vehicle people.

- Dimensional battery standards are only well-defined for the proven technology of industrial lead-acid traction batteries. For advanced electric vehicle batteries however, the evolution of the technology is such that the definition of dimensional standards would still be premature at this time. Once such technologies will have evolved enough to yield mature commercial products however, it is advisable to draft dimensional standards in order to allow a competitive market to develop, just as is the case with lead-acid batteries. Proprietary or non-standard batteries will in fact always be expensive batteries.

- Also, the standardization of voltage levels has only been established for industrial electric vehicles, where in fact the need for standard voltages is more present due to the common use of off-board chargers and the swapping of batteries. Electric road vehicles fitted with on-board chargers on the other hand are "closed systems" where the standardization of battery voltage seems to be a lesser requirement at first sight. One must recognize however that the recognition of standard voltage levels would be a great benefit for suppliers of sub-assemblies such as traction inverters or battery chargers. An effort to standardize such voltage levels would consist a welcome evolution for the future, taking into account however the ongoing developments in the field of power electronics, which tend to raise system voltages to higher levels; many electric road vehicles currently come with battery voltages exceeding 300 V. Considering the operating voltage for on-board auxiliary systems, it is likely that electrically driven vehicles will also make use of the 36/42 V system which is now being developed to replace the 12/14 V system in ICE vehicles; this will have a considerable influence on the design of auxiliary components which will have to be either conceived for the higher voltage or supplied through converters; the technological and economical impacts of these choices are still to be investigated.

- Vehicle performance standards have been prepared by both regional and international level. The new international standard ISO 8714 has the advantage to encompass several local drive cycles, and furthermore to measure energy consumption after a full discharge cycle, allowing for objective measurements for each electric vehicle design.

- Safety standards for electric vehicles have been published on both international and regional level , covering various aspects involved. Although the international standards ISO 6469 can be considered as comprehensive documents, it is to be foreseen that further revisions of this standard take into account the findings from relevant work in the field of fuel cell vehicles.

4.3 The hybrid vehicle

- Hybrid vehicle performance standards have been published on regional level, but not yet on international level. Due to the various hybrid structures possible and the plethora of drive train control strategies which can be implemented, the definition of suitable test procedures for hybrid vehicles and their drive trains is not a straightforward issue and merits further consideration.

- Battery performance standards for hybrid vehicles shall take into account the specific use pattern of the battery, which is fundamentally different from a battery electric vehicle due to the presence of an on-board energy source; this is particularly the case for non-externally-chargeable hybrids. Specific battery test cycles should be developed, preferably mimicking the usage of the battery in the vehicle test cycles.

- For externally-chargeable hybrids, which are designed to be connected to the electric supply network, relevant standardization for battery-electric vehicles should apply of course, and the scope of standards like IEC 61851 should be expanded to include hybrid (and fuel cell) vehicles where applicable, as well as considering these vehicle applications in the next edition of IEC 61851.

4.4 The fuel cell vehicle

The development of the fuel cell technology has created new challenges for standardization. The construction of an appropriate standardization landscape for this new application has allowed the structuring of effective collaboration and interaction between different standardization committees involved, avoiding double work which might lead to conflicting standards.
Although most work on fuel cell standards is still on the working group level at the time of writing, an interesting outcome can be expected.
For what concerns the standardization of test procedures for fuel cell vehicles, which may or may not be equipped with an on-board rechargeable energy storage system, the same viewpoints expressed above for the hybrid vehicle apply.

5 Conclusions

The availability of comprehensive standards covering all aspects of the electrically driven vehicle will be of great benefit to all parties concerned:

- Reliable performance measurement standards are a key factor allowing the user, and more in particular the fleet user, to assess the value of the electric vehicle products which are made available on the market. Validated standard procedures for performance measurement will undo performance claims which are given on an arbitrary basis, for publicity reasons.
  Furthermore, clear standards for performance measurement, particularly concerning energy consumption and emissions are of essential value to vehicle manufacturers to design their vehicles and to prepare them for type approval.
- Infrastructure standardization will be a key element to allow a wide market for the electric vehicle, removing its captivity and giving the user flexibility for deploying the vehicle for various missions.
- For the vehicle manufacturer good standards are to be guidelines which allow them to develop products that are acceptable for the market. Such standards should be clear and unambiguous, but not too restrictive as to constrain the manufacturer's creativity and quest for technical progress. More in particular for the small and medium sized enterprise which heavily relies on external component suppliers, well-defined component standards will enable a better view on the market in order to make the best design choices. Also, the availability of standardized components will open up the market for competition and allow for lower prices.
- The availability of and the adherence to international standards for safety will also allow vehicle manufacturers to present their products on a global market. The compliance to known and accepted standards will presume conformity to essential safety requirements and allow to gain user confidence in the product and to develop a wide market for the electric vehicle.

Standards are thus essential for the electric vehicle to corroborate its position as the efficient, safe, reliable, energetically and ecologically sound transportation means of the future.
The electrically driven vehicle is a good thing for humanity, and so is standardization.
Through continuous efforts in the field of standardization we will strive to contribute to the deployment of electrically driven vehicles, abiding by the principles of the "Electric Vehicle Creed" created as early as 1915 by the Electric Vehicle Association of America:

We Believe in the Electric Vehicle !

6 References

[1] Peter Van den Bossche, *The electric vehicle: raising the standards*, Ph.D. thesis, Vrije Universiteit Brussel, 2003

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