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The Evolving Standardization Landscape for Electrically Propelled Vehicles

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The electrically propelled vehicle makes use of various technologies and is thus faced with diverse standardization and regulation cultures. The relevant standardization landscape is a complex one, particularly if new energy vectors such as hydrogen are taken into account. The growing interest for the deployment of (hybrid) electric drive technology has given rise to specific standardization issues, which are being tackled by specific technical teams. Currently enforced rating standards to evaluate the performance of ground vehicles must in fact be adapted to hybrid electric vehicles, with particular problems arising when considering plug-in hybrids which use both fuel and mains electricity. New standards are needed to evaluate the potential benefits of the hybrid systems against the future vehicle requirements within specifically applicable bounds and regulations. The paper highlights current evolutions in the field, discussing the ongoing work programme of international standardization committees (particularly ISO TC22 SC21 and IEC TC69), and more particularly the interaction between these committees. Special attention will be given to a number of pending issues such as the definition of reliable performance and energy consumption tests for plug-in hybrid vehicles with both fuel and electricity energy supply, the specific need for infrastructure standardization and the impact of the introduction of new technologies such as hydrogen on vehicle safety standardization. The paper will report on activities in this field, providing direct feedback from the international standardization shopfloor, and will recommend specific work areas for standardization, highlighting the potential interaction of ongoing international standardization activities.

Keywords: Standardization, Regulation, Codes, Standards, RCS

1. INTRODUCTION

Standardization, on a global level, is mainly dealt with by two institutions: the International Electrotechnical Commission (IEC), founded in 1904, deals with all things electrical, whileas the International Organization for Standardization (ISO), founded in 1948, deals with all other technologies. With standardization of the electric road vehicle becoming a key issue, the question arises which standardization body would have the main responsibility for electric vehicle 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 [1], being both a "road vehicle" and an "electrical device."

One can discern a fundamentally different approach taken towards the concept of standardization in the automotive and the electrotechnical world. There is a different "standard culture," the origin of which can be traced back to historical reasons.

There is a long tradition for standardization in the electrotechnical industry, as well a stronger tendency to standardize all and everything. Electric motors are covered by extensive IEC standards covering their construction and testing. Even subjects such as the colour code of wires are standardized (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 been more common.

Electricians do not only want to define the vehicle as a whole, but also to standardize its components, on a point of view of safety, environment, quality and interchangeability.

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

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ISO	IEC
Work related to the electric vehicle as a whole	Work related to electric components and electric supply infrastructure

Table 1: Basic division of work IEC/ISO

the compliance of the equipment. Industrial electrical equipment is also designed for an extended service life: continuous operation during several years, which corresponds to up to 100,000 hours.

In the car manufacturing world on the other hand, standardization is limited to issues which are subject to government regulations (safety, environmental impact, performance measurement) and to the areas where interchangeability of components is a key issue. Since car manufacturers desire to develop their own technical solutions which embrace their proprietary technological know-how and which give their products a unique market advantage, there are few standards covering combustion engines, for example. Car manufacturers accept that a vehicle, as a whole, is subjected to safety and environmental regulations, but do not feel the need for definition of individual components.

Furthermore, the automobile is a mass-market product; extensive routine tests on every produced vehicle would be prohibitively expensive, and the customer is more likely to be a "consumer," less interested in providing the supplier with written specifications demanding compliance to specific international standards. The expected service life of an automobile (5,000 to 10,000 hours) is also much lower than of an industrial electrical machine.

This difference is further reflected in the constitution of the technical committees and their working groups which deal with electric vehicle standardization in respectively IEC and ISO. In the IEC committees many of the delegated experts are electricians or component manufacturers, whileas in ISO there is a much stronger input from vehicle manufacturers.

2. IEC-ISO ACTIVITIES ON ELECTRICALLY PROPELLED VEHICLES

Collaboration between ISO and IEC in the field of electric vehicles has been established since the foundation of the respective working groups, ISO TC22 SC21 and IEC TC 69, in the early 1970s. During the years, however, there have been considerable discussions between the two groups as to the division of the work, in which there were a number of overlaps. By the end of the 1990s, a consensus was agreed [2] defining the specific compentences of the respective committees, as shown in Table 1.

To oversee the developments in the field, a Steering Group was set up, which did overview the current work of the committee and formulated recommendations on specific issues.

3. CURRENT STANDARDIZATION ACTIVITY ON ELECTRIC VEHICLES

3.1 IEC TC69

3.1.1 WG2: MOTORS AND CONTROLLERS

The initial task of WG2 was "definition and measuring methods concerning the performance of motors and motor control systems, including protection of personnel against electric shocks and protection of electrical components." This WG was founded in 1973, and initially produced four technical reports with the intention of having these harmonized with ISO documents in a later stage. This never materialized, however, and these documents remain in the IEC catalogue up to this day without revision, even if a number of aspects covered in these documents may be considered technologically obsolete today. These technical reports are:

- o IEC 60783:1984 Wiring and connections for electric road vehicles
- o IEC 60784:1984 Instrumentation for electric road vehicles
- o IEC 60785:1984 Rotating machines for electric road vehicles
- o IEC 60786:1984 Controllers for electric road vehicles

During the early 1990s, attempts were made to revitalize WG2 in order to revise and expand these four reports into full-blown standards. From 1995 onwards, work was performed on the revision of 60785 and 60786, incorporating them into a single document in order to reflect the technological evolution which closely integrated motors and controllers. A draft has been circulated with the title "On-Board Power Equipment for Electric Road Vehicles," which had to emanate into IEC 61981. Work on this document has, however, been discontinued since 1999, following discussions in the

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IEC TC69/ISO TC22 SC21 steering group [4], mainly because the need for component standardization was not perceived by vehicle manufacturers. IEC61981 has thus been dormant as a PWI ever since, and so has WG2.

Although the idea of developing component standards for electrically propelled vehicles has not received a positive response from vehicle manufacturers, one can identify a number of issues which warrant the development of future activities for WG2. The activities of TC69 have also to be considered taking into account the fact that the term "electric vehicle" is now to be understood as "electrically propelled vehicle," which encompasses battery-electric, hybrid and fuel cell vehicles. All these electrically propelled vehicles make use of electric motors, drives and controllers, which are the province of WG2. Effective work in this field can only be done however in close liaison and relationship with relevant other committees such as ISO TC22 SC21 (electric road vehicles), IEC TC77, IEC TC21, IEC SC23H, etc. The fate of the technical reports published in the 1980s (IEC 60783 to 60786) remains to be discussed; although these documents have partly become obsolete and part of their content is now covered by other published standards (such as ISO 6469), they still treat a number of issues that are presently not covered by other standards and for which a demand for standardization has been perceived, one example being the presence of hazardous voltages on capacitors accessed during maintenance (IEC 60786, §7.1.1); this subject has received renewed interest due to the emergence of super-capacitors as peak power storage devices in electrically propelled vehicles, and the TC69 secretary has been approached by automotive standardization experts on this matter.

New activities for WG2 could encompass following topics on electric vehicle components:

- On-board power equipment; the evolution in power electronics has led to a generalized use of a.c. drive technologies, which now have nearly fully supplanted the venerable d.c. drives. The a.c. inverter used in these vehicles charges the battery during regenerative braking. It could also be used, however, to charge from an a.c. power supply at high power levels, allowing fast charging without heavy and expensive off-board d.c. charging equipment. This configuration could even be used for supply network management purposes, such as peak shaving.

The use of the traction inverter for charging has the following special features, however:

- The charging is done through a vehicle component also used for traction
- Since the inverter is, in most cases, not galvanically isolated, the whole vehicle traction circuitry becomes connected to the supply network
- A bidirectional power flow may exist between the vehicle and the supply network

The vehicle thus clearly becomes an "electric device," making it desirable to proceed to electrical standardization. To this effect, it is proposed to define new work on the following theme: electric traction equipment of electrically propelled road vehicles — connection to the electric supply network. This document would be applicable to electric power equipment on electrically propelled (battery-electric, hybrid and fuel cell) road vehicles which can be energized by both the main on-board energy source and the external electricity supply network. Examples include on-board inverters which are used for traction as well as for charging. The object of this standard is to lay down general rules for the design, installation and testing of electric power equipment on electrically propelled road vehicles and to indicate the technical requirements and testing conditions. Special attention should be given to EMC related issues for which the liaison with IEC TC77, which deals with EMC issues should be optimized.

New activities on this subject could thus be launched within the framework of IEC TC69, on the condition, however, that a clear demand for such standards can be identified.

- Electric double-layer capacitors; the use of electric double-layer capacitors (colloquially called supercapacitors) for power storage on board electrically propelled vehicles is a rapidly evolving technology. There are no standards available however concerning these components yet. To this effect, a new work item proposal on the electrical characteristics of electric double-layer capacitors [5] has been proposed in the summer of 2007 by the Japanese national commitee. Work on this item will be performed by a special task force in close liaison with the technical committees dealing with capacitors (i.e. IEC TC40).

3.1.2 WG3: BATTERIES

The initial task of WG3 was "energy storage systems, including safety of personnel against electric shocks and protection of electrical components." WG3, also founded in 1973, has performed work on the introduction of dynamic test cycles for electric vehicle batteries, leading to the amendment of the lead-acid battery standard IEC 60254-1 published in 1997 and incorporating dynamic test cycles for electric vehicle applications. This WG became very active in the mid-1990s, having published the Technical Report IEC 61382-1 defining dynamic discharge performance test and dynamic endurance test for NiCd batteries, as well as a number of other projects which did not evolve into publications.

Close collaboration of TC69 WG3 with IEC TC21 "batteries" eventually led to the regrouping of all battery standardization work to a joint working group encompassing TC21, SC21A and TC69, under the leadership of TC21. WG3 was then disbanded in 1997.

Within TC21, several standards have since been published, superseding IEC 61382-1 and the EV-related clauses of IEC 60254-1. These standards are:

- IEC 61982-1:2006 Secondary batteries for the propulsion of electric road vehicles; Part 1: Test parameters
- IEC 61982-2:2002 Secondary batteries for the propulsion of electric road vehicles; Part 2: Dynamic discharge performance test and dynamic endurance test
- IEC 61982-3:2001 Secondary batteries for the propulsion of electric road vehicles; Part 3: Performance and life testing (traffic compatible, urban use vehicles)

3.1.3 WG4: INFRASTRUCTURE

This WG was initially focused on power supply sources and chargers, including power supply sources external to the vehicle, chargers mounted or not on the vehicle, safety of personnel against electric shocks, protection of electrical components and a.c. or d.c. connectors. Its first major publication was the standard IEC 60718 Chargers for electric road vehicles, which saw different editions published in 1978, 1992 and 1997, to be eventually withdrawn in 2002.

WG4 entered a new elan in the mid-1990s to take up work on infrastructure standardization, which led to the IEC 61851 family of international standards of which the following documents have been published:

- IEC61851-1:2001 Electric vehicle conductive charging system; Part 1: General requirements
- IEC61851-21:2001 Electric vehicle conductive charging system; Part 21: Electric vehicle requirements for conductive connection to an a.c./ d.c. supply
- IEC61851-22:2001 Electric vehicle conductive charging system; Part 22: a.c. electric vehicle charging station

WG4 became dormant in 2000, however, with the following projects are still lingering at CD stage:

- IEC61851-23 Electric vehicle conductive charging system; Part 23: d.c. electric vehicle charging station
- IEC61980-1 Electric equipment for the supply of energy to electric road vehicles using an inductive coupling; Part 1: General requirements
- IEC61980-2 Electric equipment for the supply of energy to electric road vehicles using an inductive coupling; Part 2: Manual connection system using a paddle

The activities of IEC TC69 took a new start in 2007. The subject of vehicle charging infrastructure has indeed returned in the focus of interest: on one hand, the concept of "plug-in" hybrid is getting more attention due to the fact that electricity from the grid constitutes a more efficient and economical fuel; on the other hand, one should consider the poor overall energy efficiency of the hydrogen pathway (particularly if the hydrogen is generated through electrolysis) compared to the all-electric energy pathway.

WG4 took on the revision of the IEC 61851 standards in the spring of 2007 [6][7][8], and a revised version is now circulating for comments. Taking into account the subsequent stages of the process, the revised versions will be published by 2010.

3.1.4 OTHER IEC COMMITTEES

Related work in the field of infrastructure has been performed by the committees IEC SC23E and IEC SC23H which are liaised with TC69. This has resulted in two documents:

- IEC62196:2004 Plugs, socket-outlets, vehicle couplers and vehicle inlets, conductive charging of electric vehicles; Part 1: Charging of electric vehicles up to 250 A a.c. and 400 A d.c., developed by SC23H
- IEC62335 Switched protective earth portable residual current devices (SPE-PCRD) for class I and battery powered vehicle applications, prepared by SC23E and now circulated as CDV

3.2 ISO TC22 SC21

3.2.1 BATTERY-ELECTRIC VEHICLES

The ISO subcommittee dealing with electric road vehicles has been continuously active on a number of

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issues and has drafted a number of standards treating electric vehicle safety through its working group WG1:

- ISO6469-1:2001 Electric road vehicles, safety specifications; Part 1: On-board electric energy storage
- ISO6469-2:2001 Electric road vehicles, safety specifications; Part 2: Functional safety and protection against failures
- ISO6469-3:2001 Electric road vehicles, safety specifications; Part 3: Protection of persons against electric hazards

The 6469 standards are now under revision; the new edition will encompass in its scope all types of electrically propelled road vehicles (battery-electric, hybrid and fuel cell), providing a comprehensive set of standards on the safety. The safety issues for all these vehicles are indeed comparable, since they share the common electric drive train.

Work was also performed on terminology and performances:

- ISO8713:200 Electric road vehicles , vocabulary
- ISO8714:2002 Electric road vehicles, reference energy consumption and range; test procedures for cars and light commercial vehicles
- ISO8715:2001 Electric road vehicles, road operating characteristics

The ISO8713 standard will be replaced by a document now under development which will encompass comprehensive definitions of all vocabulary used in ISO TC22 SC21 standards. This document will not be published as an international standard, however, but as a technical report.

3.2.2 HYBRID VEHICLES

Performance specifications, particularly fuel consumption and emission measurement standards, are being treated by ISO TC22 SC21 WG2, which is now finalizing the following document:

- ISO 23274 Hybrid road vehicles, exhaust emissions and fuel consumption measurements; non-externally chargeable vehicles

The committee is now working on the more complicated issue of externally chargeable vehicles (plug-in hybrids) where several issues have to be taken into account, since these vehicles can be fuelled from two separate energy sources. The definition of suitable test cycles and the management of battery state of charge are treated within the working group[9], with a draft being circulated for comments on SC level [10] defining guidelines for electric charge measurement.

The safety aspects of hybrid vehicles are for the moment not treated by any standard. ISO6469 only applies to battery-electrics, although plug-in vehicles represent the same technology and thus the same hazards. The ongoing revision of this standard will address this hiatus.

3.2.3 FUEL CELL VEHICLES

The “fuel cell” can be quite rightly considered an “electrical device” since it generates electricity; its standardization would thus be a task of the IEC. To this effect, IEC Technical Committee 105 “Fuel Cell Technologies” was put in charge of preparing international standards regarding fuel cell technologies for all applications.

However, the international standardization work on fuel cell powered road vehicles has been mostly concentrated within ISO TC22 SC21. For this reason, road vehicles were excluded from the scope of the standard IEC 62282-2 “fuel cell modules” and the work on this subject was transferred to ISO.

This discussion highlights once more again the special case of the electrically propelled road vehicle, which unites automotive technology (typically standardized under the auspices of ISO) and electrical technology (typically standardized under the auspices of IEC). This dichotomy has caused similar discussions in the past about who exactly was to perform the standardization work; such discussions can only be resolved by mutual collaboration and recognition of the characteristics of each technology being put to use.

ISO TC22 SC21 has published several standards for fuel cell vehicles:

- ISO23273-1:2006 Fuel cell vehicles, safety specifications; Part 1: Vehicle functional safety
- ISO23273-2:2006 Fuel cell vehicles, safety specifications; Part 2: Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen
- ISO23273-3:2006 Fuel cell vehicles, safety specifications; Part 3: Protection of persons against electric shock

It is the intention to replace Parts 1 and 3 of this standard with the appropriate parts of the revised ISO6469 when these are published.

As for performance standards, the following document

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is now in CD stage:

- o ISO23828-1 Fuel cell hybrid electric road vehicles, energy consumption measurement; Part 1: Using compressed hydrogen

The main discussion on this document concerns the choice of methods to measure hydrogen consumption, where several methods can be used [11] (weight, pressure or flow method), each of which has its specific advantages and accuracy.

4. CONCLUSIONS

The standardization activities on electrically powered vehicles are on a high level worldwide. Experts can be found working together in the various committees in order to realize a set of documents with the aim to provide the international community with a consistent family of standards that are contextualized into a systemic approach of the Regulations, Codes & Standards problem as a whole.

With several standardization organizations active on the same subject, there is a real danger that much effort will be lost through parallel work, leading to different and potentially conflicting standards on the same topic. Such "standards" are a source of confusion and are of no useful purpose. The collaboration between different organizations, if implemented efficiently, will, however, allow standardization work to advance and to obtain positive results. To avoid the proliferation of RCS conflicts, it is recommended to put in place a mechanism to facilitate global harmonization.

It should be stressed that the different standardization bodies involved, both on organizational level (IEC and ISO), as on committee level within these organizations, should not consider themselves as competitors, but as complementary bodies, each bringing their expertise to the field. The division of standardization work on a specific subject like the electrically propelled vehicle, often grown for historical reasons, has involved a lot of discussions, which can run out of hand when each party keeps defending its turf, reasoning out of tradition and emotion. Such differences should be overcome and future standardization work should be performed in a spirit of collaboration and joint effort toward a common goal which is the drafting of clear and useful standards which benefit both the manufacturer and the user. For the electrically propelled vehicle, the idea to have vehicle aspects treated by ISO and electrical aspects treated by IEC is a reasonable solution. This whole issue needs to be followed closely at all levels, in order to optimize mutual information exchange and collaboration between ISO and IEC technical committees such as IEC TC69 and ISO TC22 SC21.

The interaction with regulations, codes and legislations — which are legally enforceable documents, necessary for type approval of vehicles — however, will necessitate the definition of further collaborative structures. The "New Approach" philosophy or the introduction of "global technical regulations" may constitute a worthful example to be followed in this framework. In the New Approach philosophy, which is now being implemented in the European Union, regulations enforced by the government (e.g. EU directives such as the machine directive, low voltage directive or pressure vessel directive) define "essential safety requirements," but do not state technical details. For these, reference is made to European or international standards. These standards remain standards; that is, they are voluntary, but complying to the standard implies complying to the directive.

For road vehicles, however, this system has not yet been implemented, the type approval regulations being issued by the UNECE, an United Nations body which is beyond the level of the EU only. The advantages of the New Approach are clear since the discrepancy between standards and regulations is eliminated, and the restriction of technological development through obsolete specifications enshrined in legislation or overspecification by overzealous legislators can be avoided. The issuance of technical specifications by political legislative bodies without a solid technical base may in fact give rise to unusual, inadequate or foolish specifications which do not establish a tangible benefit nor for the manufacturers nor for the end users of the technology involved. However, one has to recognize that the main vehicle manufacturers are not in favor of the adaption of the New Approach for road vehicles on the EU level, since it deviates from existing, proven practices and could introduce additional discrepancies with the rest of the world which is covered by UNECE and might be covered by global technical regulations. The situation for road vehicles, the type approval of which is defined by international regulations, stands in contrast with the situation for stationary applications, where no international regulating body responsible for harmonizing regulations exists.

Figure 1 shows the various interactions which are necessary for this harmonization. In order to ensure that standards are properly used in regulations, both the standards bodies and regulatory bodies have to intensify joint cooperation on all levels.

An "ideal" RCS landscape would follow a New Approach philosophy, with international standards on all appropriate technical matters, and globally accepted

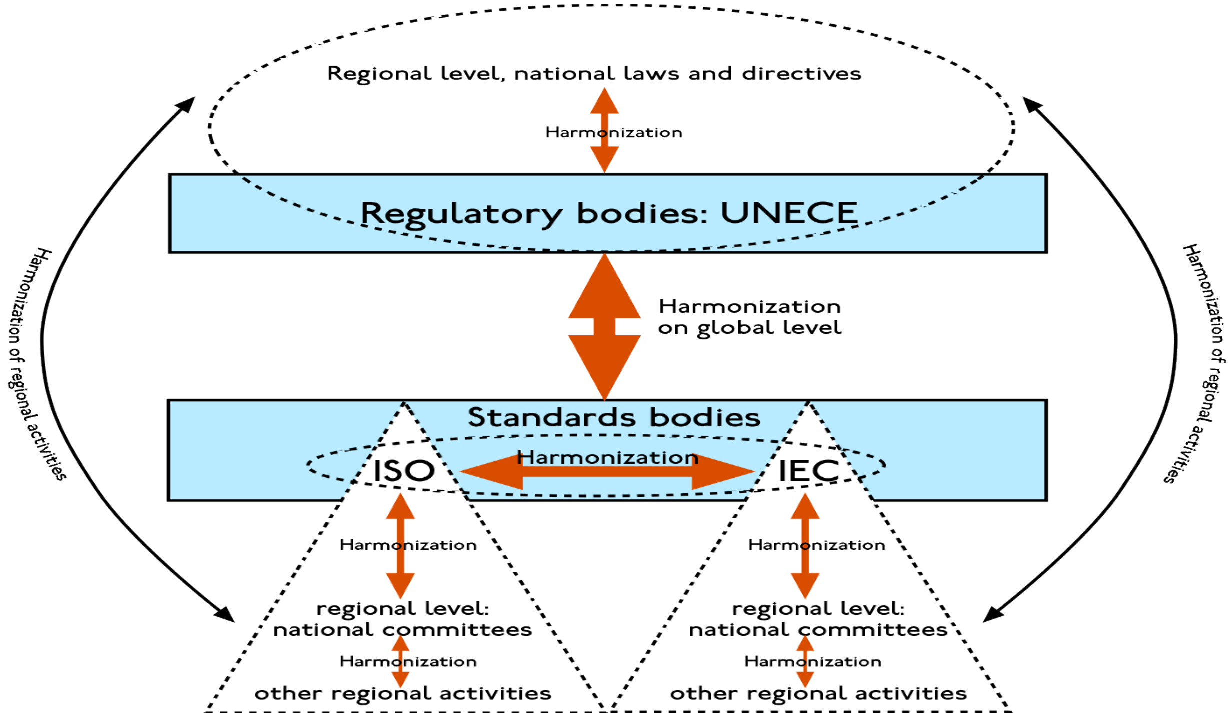

Figure 1: Standardization collaboration and harmonization

technical regulations referring to these standards. All RCS work would be closely coordinated in order to avoid parallel or conflicting work. Also, RCS work should be targeted to relevant subject in order to avoid bad practices such as overstandardization, or what is even worse, overregulation.

The mutual collaboration of competent engineers will always remain the keystone of effective standardization work to the benefit of society as a whole.

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