38th International Electric Vehicle Symposium and Exhibition (EVS38)
Göteborg, Sweden, June 15-18, 2025

Stan4SWAP: towards efficient standards for Light Electric Vehicle Battery Swap

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Executive Summary

Light electric vehicles within the L category are expected to play a significant role in promoting sustainable urban transport, advantageous for both society and the environment. The batteries in these vehicles are well-suited for swapping, necessitating appropriate standards. This paper outlines the standardization framework relevant to this application, as studied by the ongoing European Stan4SWAP project. It reports on the outcomes of the project and more particularly on the evolution of standardization work in the field.

Keywords: standardization, electric two- & three-wheelers, charging business models

1 Introduction

Figure 1: Stan4SWAP

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. Light (L-category) vehicles can have a contribution to cutting greenhouse gas emissions as set by the European Green Deal. Issues such as range anxiety remain however, but may be tackled with swappable battery systems (fig. 2). Battery swapping is an innovative system allowing owners of electric light vehicles to swap out their discharged batteries for fully recharged ones in a matter of seconds, eliminating long recharging stops and allowing flexible vehicle operation. This system has the potential to revolutionize electric mobility, facilitating the widespread adoption of electric vehicles. Standardizing battery designs and interfaces however presents obstacles, limiting interoperability between vehicle and battery makers.

The European Stan4SWAP project (fig. 1) aims to speed up the market introduction of interchangeable battery systems for light vehicles. By creating a standardization roadmap, Stan4SWAP intends to guarantee interoperability and compatibility between vehicles and batteries from various manufacturers, thereby encouraging the uptake of battery-electric L-Cat vehicles. Alongside addressing the technical, market, and regulatory issues, as well as promoting education and awareness about the importance of standardization, one primary goal is to pinpoint the specific needs and challenges linked to swappable battery

systems to aid their market launch and increase stakeholder involvement. The needs identified for swappable battery systems along with those for pre-normative research provide the foundation for spotting standardization gaps and tackling them in the standardization plan. [1]

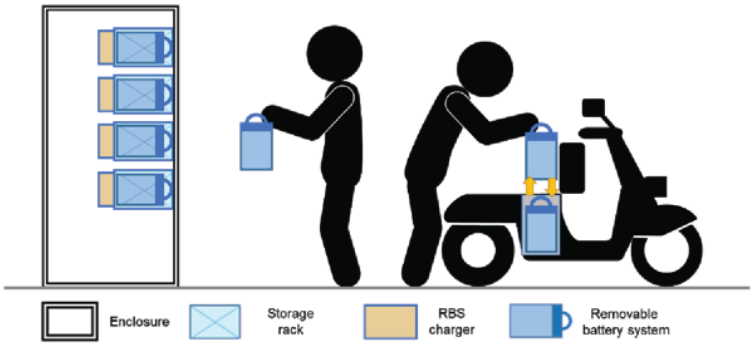

Figure 2: Manual swapping station layout [2] © IEC

2 Regulatory background [3]

Although standards and regulations are fundamentally different concepts, it is interesting to look at some European regulatory instruments, as these have an influence on the development of harmonized European standards through the standardization mandates issued by the European commission to CEN and CENELEC.
Recent relevant regulations include the new Battery Regulation - Batt-R – (2023/1542) [4], which specifies mandatory requirements for all batteries placed on the EU market, covering sustainability and safety, labelling, marking and information, due diligence, waste battery management and recycling, battery passport, green public procurement.
Of interest is also the Alternative Fuels Infrastructure Regulation - AFI-R – (2023/1804) [5], which sets binding national targets for the development of EU alternative fuel infrastructure. It also establishes common technical specifications and requirements regarding the information to vehicle users for the provision of data and payment requirements, as well as the low voltage directive (LVD) (2014/35/EU) [6] which ensures that electrical equipment provides a high level of protection for European citizens.

3 Relevant Standardization work [3]

3.1 Introduction

To make a battery swapping system practical, it is crucial to have standardized specifications across various manufacturers and models. The varied European automotive industry, featuring a wide range of manufacturers and vehicle types, poses a notable challenge to standardization. Without unified standards for battery dimensions, shape, and connectivity, the system's interoperability remains constrained.
The standardization work relevant to the subject is mainly done within IEC regarding the infrastructure issues, with specific vehicle-based aspects covered by ISO. Most work takes place at global level, with the resulting international standards being adopted as European ones by CEN and CENELEC
The main committee dealing with charging infrastructure standards is IEC TC69.

3.2 Battery swapp standards: IEC 62840

The subject of swappable batteries is covered by the IEC 62840 family of standards "Electric vehicle battery swap system". Its Part 1 "General and guidance" [2] was first published as Technical Specification in 2016, and made it to International Standard level in 2025.
This first part gives a general overview of battery exchange systems for electrical road vehicle batteries, introducing system concepts and use cases. It marks the difference between "swappable" and "removable" battery systems, describing typical system components for both. The swappable battery system, where the batteries are moved by the charging station handling system, is foremostly aimed at larger vehicles (cars and heavy duty vehicles), whileas the removable system aims at lighter vehicles such as covered by

the project. An example of removable battery system is given in fig. 2.

The second part on "Safety requirements", was published as international standard in 2016 [7], and will see its second edition by the end of 2025. It contains the general safety requirements for swappable or removable battery systems. The battery swap system shall be so designed and constructed that in normal use its performance is reliable and minimizes the risk of danger to the human individuals, equipment and surroundings. Specific additional aspects related to the application are covered including the operational safety of the vehicle lane system, the battery handling and storage systems, removable/swappable batteries and chargers. Special attention is given to electrical safety requirements.

The third part of IEC 62840, dealing with particular safety and interoperability requirements for battery swap systems operating with removable RESS/battery systems, has had a checkered history.
Initially, this document was intended to be part of the IEC61851-3 series, aimed at the conductive charging of "light electric vehicles" (LEV). The exact definition of LEV proved however to be difficult, as it depended on varying national regulations taking into account factors like weight, number of wheels, maximum speed,… which are hardly related to the electrical safety aspects of the charging process which were the real scope of the standard. For this reason, the documents of the 61851-3 series refer to "DC EV supply equipment where protection relies on double or reinforced insulation" which is in fact the protection method most widely used for LEV. Such "Class II" equipment shall not be earthed. The various parts of IEC 61851-3 were eventually published as Technical Specification in 2023. The third part 61851-3-3 however, dealing with removable battery systems, was taken out of the series and transferred to the 62840 project. It was decided to publish the document as a "Publicly Available Specification" based on the existing draft, as an intermediate document that meets specific market, which has been published prior to the development of a complete international standard. As such, IEC PAS 62840-3 was still heavily indebted to 61851-3 series [8].
The new version however, which is now at Committee Draft level, will be fully integrated into the IEC 62840 series.
The new part 3 provides specific requirements and test methods for battery swap systems operating with handheld - swappable battery systems (HBS) of totally or partly electrically propelled vehicles. It extends parts 1 and 2 with specific requirements for the give application.

3.3 Other relevant standards

The light electric vehicles with swappable batteries considered by the Stan4SWAP project cover various technology realms involving several other standardization committees, such as

- Accessories (IEC SC23H)

  Accessories to be used with the considered systems are covered by IEC SC23H, of which two documents are particularly interesting:

  - IEC/TS 62196-4 [9], covering the dimensional compatibility and interchangeability requirements for DC pin and contact-tube accessories for Class II or Class III applications, with Class II and III referring to the measures taken to protect against electric shock: double or reinforded insulation for Class II and extra-low voltage for class III.
  - IEC 63066, first published as Technical Specification in 2017 [10] and expected as International Standard in 2025, covers low-voltage docking connectors for removable energy storage units.

    Pluggable energy storage technology has a large demand and perspective in certain areas. With the advent of electric vehicles, energy storage units for renewable energy and other applications, guidance is needed to ensure safe and reliable operation, interoperability, environmental protection and energy efficiency. The industry needs such a standard to promote the technology development and popularization of pluggable energy storage technology.

    In comparison to other accessories, certain specific items are taken into account. The operator might not have tactile feedback during the mating process to correctly align the two parts of the connector. Additionally, a mechanical feed in the mating process might prevent proper alignment of the connector parts. To address these challenges, the accessory design may include movable components to compensate for mechanical feed and tolerances.

    IEC 63066 applies to docking connectors incorporated in or fixed to electrical equipment, intended to connect removable energy storage units to a dedicated electric power conversion unit, to an energy consuming unit or to another energy storage unit.

    Requirements are given for electrical and mechanical properties of the accessories; these requirements are largely based on IEC60309-1 – the general standard for industrial plugs and connectors – amended where necessary for the specific needs of docking connectors.

    The document defines three types of accessories in standard sheets, among them a docking connector rated 60V, 50A for battery swap systems under IEC/PAS 62840-3.

- Battery safety (IEC TC21, IEC SC21A, CLC TC21X, ISO TC22 SC37, ISO TC22 SC38) As for standardization of batteries and their safety aspects, several committees are active each with their specific approach.

  When the battery is considered as a system in he vehicle, the main work comes from vehicle committees such as ISO TC22 SC37 with the general safety standard ISO 6469-1 [11] for EV batteries or ISO TC22 SC38 with the ISO 18243 [12] which specifies the test procedures for lithium-ion battery packs and systems used in electrically propelled mopeds and motorcycles.

  A specific European development has been the EN 50604 "Secondary lithium batteries for light electric vehicle" [13], specifying test procedures and providing acceptable safety requirements for voltage class A and B (i.e. below or above 60V DC) removable lithium-ion battery packs and systems, to be used as traction batteries of or for electrically propelled road vehicles.

  This standard is primarily system-oriented — excluding individual cells — and is to be considered in conjunction with the ISO standard 6469-1, supplementing or modifying the corresponding clauses in the ISO standard.

  The selected test items are designed to replicate scenarios that may happen during handling (such as removal or replacement) or during use, including normal operation, rough handling, and potential misuse or negligent handling.

  For the safety aspects on cell level, these standards refer to the IEC 62660 series "Secondary batteries for the propulsion of electric road vehicles", where Parts 2 [14] and 3 [15] deal respectively with safety testing and safety requirements for battery cells and modules.

  Although these standards primarily aim larger vehicle batteries, cells covered by IEC 62660 are also likely to be used in LEV applications, albeit in smaller systems than for heavier vehicles.

  For portable secondary lithium cells and batteries, there is the IEC 62133-2 [16] standard drafted by IEC SC21A, which specifies requirements and tests for the safe operation, considering both intended use and reasonably foreseeable misuse, the latter defined as use in a way which is not intended by the supplier, but which may result from readily predictable human behaviour.

  This standard covers a wide array of cell types and sizes, some of which may be applicable for LEV battery assemblies.

- Battery chargers (IEC TC61) Battery chargers for light electric vehicles often are considered akin to household appliances and ruled by corresponding standards such as IEC 60335-2-29 [17] and IEC 60335-1 [18]. These documents also serve as basis for IEC/TS 61851-3-2 [19], which supplements or modifies the 60335 requirements and tests for mechanical and electrical safety.

  General standards on functional electrical safety such as IEC 61508 [20] may also be applicable. This standard provides a generic framework for all safety lifecycle activities involving systems composed of electrical, electronic, and/or programmable electronic (E/E/PE) elements that perform safety functions. This standardized methodology aims to establish a rational and consistent technical policy for all electrically-based safety-related systems. The standard introduces safety integrity levels for specifying the target level of safety integrity for the safety functions to be implemented. This document has a broad scope of application and is not specifically aimed at swappaple battery systems.

- Protocol standards (IEC TC69 There is substantial standardization activity on communication protocols, the most famous example being the Open Charge Point Protocol (OCPP), a widely used consortium standard developed by the Open Charge Alliance (OCA), tha was recently enshrined as IEC International Standard IEC 63584 [21]. This document reflects OCPP 2.0.1 and does not refer to battery swapping.

  However, the latest version 2.1 [22], released by OCA and underway to implemented as IEC document 63584-210 through the fast-track procedure; features a new section that describes use cases for the control of a battery swap station. Battery swapping differs from conventional charging in that a battery swap action cannot be recorded by the usual OCPP messages. The action of swapping a battery is not considered a charging transaction; instead, it is a separate service. OCPP 2.1 introduces a new use case to record the swapping of batteries.

4 Standardization gaps and the need for new standards

The design of a standardization roadmap for swappable batteries will be the main aim of Stan4SWAP project. One main point will be the identification of main standardization gaps where additional measures have to be taken.

A first domain where new standardization might be needed concerns battery specs. Battery-related standards are well developed in the fields of safety (see above) and performance measurement. For lithium batteries, there are no standard sizes for cells or modules, contrary to mature battery technologies like lead-acid; lithium technology is in fact still developing and too strict standardization might hamper development.

In order to deploy swappable batteries on a sufficient wide scale (addressing different vehiclle models from different manufacturers), standardising battery sizes and specifications will be necessary in order to allow compatibility and interoperability, for both battery and vehicle manufacturers.
Drafting such standard battery specifications is a complex issue however, with the realisation of full interoperability and compatibility particularly challenging, especially involving different brands.
Initiatives in this field have been taken by the "Big Four" motorcycle manufacturers in Japan — Honda, Yamaha, Suzuki, and Kawasaki — and by the international "Swappable Battery Motorcycle Consortium" (SBMC), aiming to standardize swappable battery systems for L-category electric vehicles.
Such standard batteries will allow interchangeability whilst meeting durability standards to withstand the demanding environment of frequent swapping and manipulation. The swapping procedure shall be user friendly and foolproof. They form part of an ecosystem consisting of tghe battery cells proper and the battery management system (BMS), interacting with the two biotopes of the swappable battery: on one hand the vehicle and on the other hand the charging station.
The battery shall also comply with regulatory requirements set out in the Battery Regulation [4] concerning durability, health monitoring and recycling.

A typical battery expected to be used in this application typically would have a voltage of 48 V, an energy content of 1,6 to 2 kWh, a peak charging power of 3 kW, and a peak output of 6 kW, all this packed in a unit of no more than 15 kg weight [23].

New standardization work on LEV swappable batteries, besides the activities on IEC 62840-3 cited above, has started on European level with the inception in CEN TC301 of a new working group WG19 on Swappable battery system for L-category vehicles.

5 Stakeholders involved

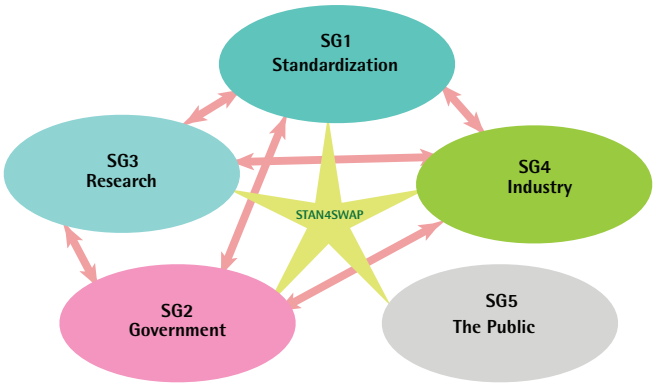

Figure 3: Stakeholder groups

Considering the technical an societal impact of battery swapping technology standardization for light electric vehicles, one should realize that this exercise goes beyond single parties. A wide array of stakeholder groups are in fact involved (fig. 3), of which the mapping will allow a targeted approach for reaching the desired objectives and adding value to the project. The interaction between the various parties shall be optimized in order to obtain the optimal standardization, framework addressing the needs of all concerned.

1. Standardization committees and organizations.

   Several global and regional standards outline the criteria for safety, compatibility, and performance of replaceable battery systems. Much of the standardization in electrotechnology is performed by the IEC worldwide, while CENELEC both adopts international standards as European standards and drafts specific standards for Europe when necessary. For the vehicle side, standardization is performed by ISO and CEN respectively.

2. Government services.

   Public authorities are responsible for defining the policy and regulatory framework providing the framework for the deployment of environmentally friendly mobility and the related infrastructure. The authorities are established at different levels according to the subsidiarity principle: European, national and local, defining the regulatory framework and promoting specific developments:

3. Research and academic interests.

   The influence of scientific research and development on innovation is paramount. Academic research is performed at universities where major research groups are focusing on electric mobility. A further channel is through fellow European research projects, funded by public authorities or by industry. A key role is also foreseen for research-focused organizations providing funding or co-ordinating R&DI activities.

4. Commercial and industrial actors.

   The industrial sector regroups key actors in product development. The enterprises involved cover several domains such as the manufacturing industry (involving not only the vehicles proper, but also subsystems or ancillary infrastructures), the energy industry and the services industries .

5. The general public.

   The general public is end user of the technology, and its choices will be measuring the technology's success.

6 Conclusion

Reaching interoperability of batteries among various vehicles and swapping stations is an ambitious goal which will benefit users by removing range anxiety, reducing charging time an- lowering end user costs. Furthermore, it will facilitate re-using and repurposing batteries for a second life application, aligning with a circular economy approach.
In order to realize these objectives, an optimised standardization landscape is necessary. The standardization roadmap being drafted through the Stan4SWAP project, which will be available with the conclusion of the project by the end of 2025, thus represents a key element towards the deployment of effective battery swapping systems for light electric vehicles.

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Acknowledgments

This paper emanates from the European research project Stan4SWAP (Horizon Europe grant agreement No. 101135417)

We acknowledge Flanders' Make for the support to our research centre.

Presenter Biography

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