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Metrological aspects of introducing charging stations for electric vehicles

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Abstract

Electric mobility is a rapidly evolving field, so electricity is considered one of the main alternative fuels. Electricity is a particularly attractive source of energy, which is used for electric vehicles (EVs) in urban/suburban agglomerations and other densely populated areas. An extensive network of EV charging stations is a major factor for using electric vehicles.

The main method of EV charging is to connect the on-board charger to the AC power supply. An alternative method of EV charging is to connect the outboard charger to the DC power supply. There are three main options to connect an EV to a charging station: using a special power cable; with a pantograph; via wirelesses connection. A standardized interface between the electric vehicle and infrastructure seems to be one of the most topical challenges in the world of electric mobility.

International standards cover payment accounting systems for electricity and provide specifications on the equipment and protocols for meter data exchange. There is an urgent need to draw up national or regional metrological regulations for EV charging. The issue of international and regional standardization of DC electricity meters for using at charging stations remains pressing.

Keywords: charging station; electric vehicle; electric bus; charging connector; smart measuring system; electric meter.

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1. Introduction

Electricity is a particularly attractive source of energy, which is used for electric vehicles (EVs) in urban/suburban agglomerations and other densely populated areas. It can facilitate air quality and reduce noise. In addition, electricity can increase the efficiency of land vehicles and at the same time reduce CO_2 emissions. Electric mobility is a rapidly evolving field and a weighty contribution to the European Union's (EU) climate and energy goals. Directive 2009/28/EC [1] sets binding targets on sharing energy from renewable sources for transport sector. In the European Alternative Fuels Strategy, electricity is considered as one of the main alternative fuels with the potential for long-term oil substitution.

The lack of a harmonized alternative fuel infrastructure in the EU has prevented the launch of vehicles using alternative fuels. Directive 2014/94/EU [2] establishes an action plan for a competitive and sustainable automotive industry in Europe. The plan includes the deployment of a new infrastructure required at the national level of Member States, including various options for access to charging stations. It is necessary to create a public infrastructure for supplying electricity to appropriate vehicles. EV charging points should be accessible to the public and built with sufficient coverage.

Ukraine is one of the world leaders demonstrating growing rate in selling EVs. An extensive network of EV charging stations is the major factor for using EVs with the possibility to move not only within city settlements, but also to travel on long distances. One of the problems holding back the development of electric mobility in this country is the unaddressed issue of equipping places with EV charging stations. This causes difficulties in designing networks of EV charging stations, which prevents the further promotion of EVs due to the low charge of battery. These issues are regulated by current legislation [3], adopted in 2019.

Charging of EVs should use smart measuring systems defined in Directive 2012/27/EU [4] to promote the stability of electricity systems by recharging batteries from grids during low overall electricity demand. Such

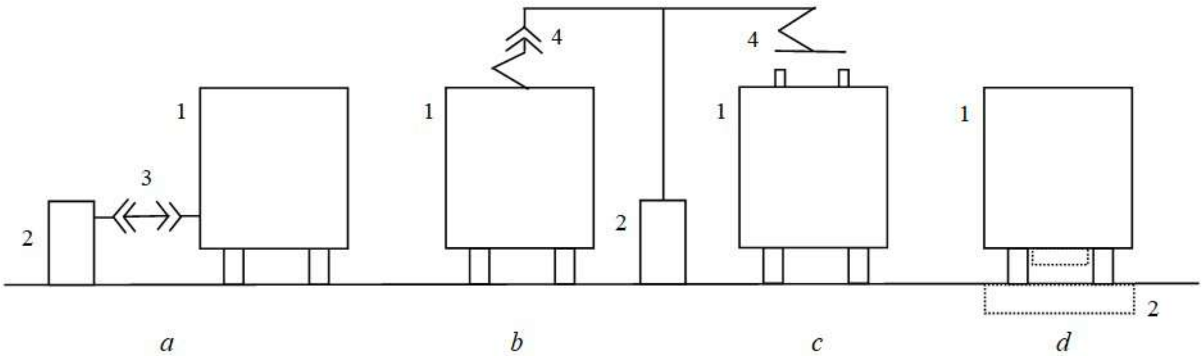

Fig. 1. Options for connecting EV to charging station: 1 – EV; 2 – charging station; 3 – power cable; 4 – pantograph

systems allow obtaining real-time data necessary to ensure network stability and stimulate the rational use of recharging services. Smart measuring systems provide accurate and transparent information owing to the availability of recharging services supporting recharging during "off-peak" periods, which means low overall electricity demand and low costs on energy. The use of such systems optimizes recharging, which benefits the electricity system and consumers. For recharging points of EVs, which are not publicly available, it is necessary to strive for introducing smart electricity meters.

The issues regarding standardization of various components, which are required for the operation of EV charging stations at the international and regional levels, have not been addressed yet. The issue of metrological support of EV charging stations is also pressing.

2. Features of using EV charging stations

According to the IEC standard 61851-1 [5], the EV is any vehicle driven by an electric motor that receives current from a rechargeable storage battery or other mobile energy storage devices, which is intended primarily for using on streets, roads, and highways. The alternating current (AC) EV charging station is all the equipment needed to supply AC, enclosed in a shell and endowed with special control functions. The direct current (DC) EV charging station is all the equipment needed to supply DC, enclosed in a shell, endowed with special control and communication functions and placed outside the EV.

The main method of EV charging is to connect the on-board charger to the AC power supply. An alternative method of EV charging is to connect the outboard charger to the DC power supply. Special chargers operating at high current levels are used for fast EV charging. The rated voltage of the AC supply AC for a charger shall not exceed 1000 V. The equipment shall operate properly within ± 10% of the standard rated voltage. The nominal frequency value is 50/60 Hz ± 1% [5].

There are three main options to connect an EV to a charging station (Fig. 1) [6]: using a special power cable (Fig. 1*a*); with a pantograph from bottom to top (Fig. 1*b*) and from top to bottom (Fig. 1*c*); via wirelesses connection (Fig. 1*d*).

There are four types of charging EVs using a power cable or so-called "manual connection" [5]. Type 1 charging is the connection of the EV to the AC power supply using the power supply side of the standardized plug sockets up to 16 A with the voltage up to 250 V (AC single-phase) or 480 V (AC three-phase current) as well as power and protective earth conductors. The use of Type 1 charging is prohibited in national standards. Type 2 charging is the connection of the EV to the AC mains up to 32 A with the voltage up to 250 V (AC single-phase) or 480 V (AC three-phase current) using standardized single-phase or three-phase sockets, power conductors and protective earth conductors together with the control function and personal protection system to avoid electric shock between the EV and charging station. Type 3 char-

a *b*

Fig. 2. Options for connecting EV to charging station

Fig. 3. Options for connecting electric buses to charging stations

ging is the connection of the EV to the AC power supply network using a specialized linear control unit. Type 4 charging is the connection of the EV to the AC power supply using an outboard charger, in which the control function extends to the equipment, which is permanently connected to the AC power supply.

Options for connecting the EV to the charging station are shown in Fig. 2: *a* – mobile charging station (Fig. 2*a*); *b* – stationary charging station (Fig. 2*b*).

Charging with a pantograph and first type of "automated connection" provides highly located wired energy transmission in a very short period from a charging system to heavy vehicles such as electric buses, trucks, and special vehicles in harbours and airports. Wireless charging (induction charging) with the second type of "automated connection" is wireless charging through electromagnetic fields, when the current is transferred to the EV. The field starts charging when the electric car is parked at the charging point or driven over an induction plate located on the road surface of a parking space [6].

The European Organizations for Standardization CEN/CENELEC is working on further standardization and harmonization of such charging methods so that vehicles and charging equipment of different brands can be charged without problems in terms of compatibility.

Protection against electric shock and charging cable requirements are regulated by the IEC standard 61851-1 [5]. Electrical parameters and characteristics, electrical insulation characteristics of charging cables, as well as their testing, are regulated by the IEC standard 61851-1. According to the IEC standard 61851-1, the immunity test is carried out according to the IEC standard 61000-6-1 [7], and the emission test is carried out according to the IEC standard 61000-6-3 [8].

3. Features of using charging stations for electric buses and heavy-duty EV

Two types of charging pantographs are used for electric buses (Fig. 3) [6]: "top-down" or "inverted pantograph" (Fig. 3*a*), which is an integral part of any charging infrastructure, and "top-up" or "rooftop pantograph" (Fig. 3*b*). Top-down pantographs are often used at the beginning of a route, at bus stops or at the end of a route. In these places, the bus is charged for a very short period, which is also called "charging if possible". The most common type of pantograph charger is a "rooftop pantograph", which is used on the route or at the bus station, where charging is very fast. Pantograph charging has the advantage that it can also be used for slow charging at night without cables scattered around the station. Charging with a power cable is also used at bus stations (Fig. 3*c*).

The standardized interface between the EV and infrastructure seems to be one of the most pressing issues in the world of electric mobility. To ensure the compatibility of the interfaces of electric buses and charging stations, a special ZeEUS project has been initiated. The project has worked out special recommendations aimed at describing the processes and needs of operators. The CEN-CENELEC eMobility steering group cooperates closely with the ZeEUS project. At the same time, a group of bus manufacturers and charging infrastructure suppliers, including ABB, Heliox, Irizar, Siemens, Solaris, VDL and Volvo have announced their open charging interface agreement. This will ensure the compatibility of electric buses with the charging infrastructure based on an open charging interface [9].

Many EU countries are planning to move towards fossil-fuel-free transport systems by replacing fossil fuel buses with zero-emission electric buses. To ensure fast integration of these vehicles in charging infrastructure, a set of unified standards for charging electric buses is required. In [10], the ASSURED project and activities of other projects are presented with the aim to achieve interoperable and reliable heavy-duty EV fleets. In [11], a pre-normative roadmap is presented that foresees developments in charging heavy-duty EV. The roadmap supports and facilitates future efforts in the standardization of charging technologies by creating an overview of the popularity of charging technologies and the end users' needs. According to the findings, a pantograph on the roof of a vehicle and plug-based charging are currently the most popular charging interfaces.

Regulation 2021/1444/EU [12] supplements Directive 2014/94/EU [2] on the deployment of a new infrastructure based on alternative fuels, as regarded by the standards on recharging points for electric buses. CEN and CENELEC have developed and adopted appropriate European standards containing technical specifications on recharging points for electric buses. Type 2 connectors, according to 62196-2/EN [13], are the most appropriate type for normal and high-powered AC recharging points for electric buses. The standard 50696/EN [14] is applied to contact interface automated devices for conductive recharging electric buses in mode 4 (voltage up to 1500 V (DC)), according to 61851-23-1/EN [15]. These standards play a crucial role for the deployment of electric buses in European cities.

4. The standardization of communication equipment for EV charging stations

In [16], new standards for EV fast charging are analysed and the impact of standardization challenges on the stakeholders are considered. The review has revealed three primary standardization issues: charge connections, car to charger communication protocols, and charge payment options. International standards from the IEC are basically transformed into European CENELEC standards without changes. If any amendments are made, a special application ZZ is added, which establishes a link between individual articles of EU legislation and clauses and sub-clauses of an international standard.

International standards from the IEC (series 62055) cover payment systems for electricity metering that in turn cover customer information systems, points of sale systems, token carriers, payment counters, and corresponding interfaces existing between these facilities. The Standard Transfer Specification (STS) is a secure messaging protocol that allows information to be transferred between the Point of Sale (POS) equipment and payment counters. The STS serves several types of messages, such as credits, configuration controls, displays, and test instructions. The IEC standard TR 62055-21 [17] provides a basis for integrating standards in specification system for electricity bill accounting systems. It deals with using payment accounting system, general processes, common functions, data elements, system objects and interfaces that exist in modern payment accounting systems.

The standard 62055-31/EN [18] is applied to newly manufactured static watt-hour meters of accuracy classes 1 and 2 for direct connection to measure AC power consumption in the range of 45 Hz to 65 Hz including a load switch to interrupt or resume power supply according to the current value of the available credit supported in the payment counter. This is not applied to static watt-hour meters where the voltage at the connection terminals exceeds 600 V (boundary voltage for meters in multiphase systems).

The IEC standard 62055-41 [19] defines the STS protocol used to transfer credit units and other management information from the POS system to the STS-compliant payment counter. It is intended for the use by payment meter manufacturers to provide bills for electricity without a rate. The IEC standard 62055-51 [20] defines the STS physical layer protocol for the transmission of credit units and other management information between the POS system and the STS-compliant electricity meter. The IEC standard 62055-52 [21] defines the STS physical layer protocol for transmission of credit units and other management information between a client and a server over a direct local connection. It goes in addition to the application layer protocol specified in the IEC standard 62055-41 [19] and should be used together with this standard. It is designed to be used in some payment counters designed by different manufacturers and to ensure compatibility between these products and other client devices.

The IEC standard 62056-21 [22] describes hardware and protocol specifications for local meter data exchange. In such systems, a manual unit or a device with equivalent functions is connected to a rate device or group of devices.

5. Measuring instruments for EV charging stations

There is an urgent need to draw up national or regional metrological regulations for EV charging due to active expansion of networks for such charging stations. It is necessary to ensure the reliability of electricity measurements during recharging of EVs.

The EU Member States are introducing smart measuring systems and smart electricity meters in accordance with Directive 2009/72/EC [23]. Accounting systems should provide end-users with information about the actual time of use. Energy efficiency goals should be considered when setting the minimum functionality of meters. Smart measuring systems must ensure the security of smart meters and the transmission of meter data, which shall be available to the end user.

In the EU, the national legislation on the metrological activity in Member States for active electricity meters is harmonized with the Measuring Instruments Directive (MID) [24]. In this case, the EV charging station may contain a meter for measuring AC electrical active energy, with a conformity assessment already performed. Otherwise, a separate conformity assessment can be performed for an EV charging station with a meter for measuring AC electrical active energy as a whole [25].

European standards (series 50470/EN) are related to the requirements of the MID [24]. Those standards are applied to newly manufactured watt-hour meters for residential, commercial and light industrial use in 50 Hz electrical networks with voltage up to 1000 V (AC). The standard defines general and special requirements and methods of type tests. The standard 50470-1/EN [26] is applied to electromechanical or static meters for indoor and outdoor use that measure AC active electrical energy. The standard 50470-2/EN [27] is only applied to electromechanical meters, and the standard 50470-3/EN [28] is only applied to static meters for measuring AC electrical active energy.

The issue of international and regional standardization of DC electricity meters for using in EV charging stations remains relevant. The international Standard of the IEC 62053-41 [29] is applied only to static watt-hour meters for measuring DC electrical energy, and it is also applied to standard tests only. The standard is applied to electricity meters for electrical networks with voltages up to 1500 V (DC). Such electricity meters can be used at public charging stations for DC EVs.

In 2020, the German Commission on Electrical, Electronic and Information Technologies (DKE) prepared the standard VDE-AR-E 2418-3-100 [30] for measuring systems at EV charging stations. It includes system aspects related to data processing, storage and transfer, as well as the requirements for AC or DC active electricity meters. In 2020, to prepare a technical infrastructure for EV supply equipment within legal metrology, some metrological institutes from different European countries initiated a joint project LegalEVcharge (EURAMET TCEM project No. 1539) [25]. The project is based on the Ministry of Foreign Affairs. In 2021, NordCharge, a Nordic cooperation on charging stations for electric vehicles operating under metrological regulation, began its work. NordCharge has prepared a Guide for bringing EV supply equipment to market. The Guide is based on existing legal requirements, such as the MID [25].

OIML TC 12 “Instruments for measuring electrical quantities” is actively involved in the work in this rapidly developing new field of legal metrology. In 2021, a new Project group P3 “Charging stations for electric vehicles” was created within OIML TC 12 to prepare a required guide [25]. As a part of this project, a draft OIML Guide “Electric vehicle supply equipment” is being prepared in two parts: Part 1: “Metrological and technical requirements” and Part 2 – “Metrological control and performance tests”.

The draft of the standard 50470-4/EN is also being prepared for meters of active DC electric energy [31]. The standard will be applied only to static watt-hour meters for measuring DC electrical energy and to standard tests. The implementation of this standard can ensure the conformity assessment of DC electricity meters used at EV charging stations. In the future, it is advisable to extend the MID with DC meters.

6. Conclusion

Creating an infrastructure for EV charging stations and ensuring accessibility for their users is an urgent task. For successful implementation of this task, it is necessary to address the issues of standardization of various components required for the operation of EV charging stations at the international and regional levels. The issue of full metrological support for EV charging stations may be addressed by standardizing the requirements and test methods for DC electricity meters.

Метрологічні аспекти впровадження зарядних станцій для електромобілів

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Анотація

Електрична мобільність є сферою, що швидко розвивається, тому електроенергія розглядається як один з основних альтернативних видів палива. Електрика є особливо привабливим джерелом енергії для використання електромобілів у міських/приміських агломераціях та інших густонаселених районах. Розгалужена мережа зарядних станцій для електромобілів є основним фактором використання електромобілів. Заряджання електромобілів має використовувати інтелектуальні системи вимірювання для підвищення стабільності електричної системи шляхом підзарядки батареї від мережі під час низького загального споживання електроенергії.

Основним методом зарядки є підключення електромобіля до джерела живлення змінного струму. Альтернативним методом зарядки є підключення електромобіля до джерела живлення постійного струму. Існує три основних варіанти підключення електромобіля до зарядної станції: за допомогою спеціального кабелю живлення; за допомогою пантографа; бездротове підключення. Стандартизований інтерфейс між електромобілем та інфраструктурою здається однією з найнагальніших проблем у світі електричної мобільності. Для контактних інтерфейсів для зарядних станцій використовується напруга змінного струму до 1000 В і напруга постійного струму до 1500 В.

Міжнародні стандарти охоплюють платіжні системи обліку електроенергії, надають специфікації обладнання та протоколів для обміну даними лічильників. Існує нагальна потреба в розробці національних або регіональних метрологічних правил для зарядки електромобілів. Зарядна станція може містити лічильник для вимірювання електричної активної енергії змінного струму з уже проведеною оцінкою відповідності. В іншому разі можна провести окрему оцінку відповідності для зарядної станції. Актуальним залишається питання міжнародної та регіональної стандартизації лічильників електроенергії постійного струму для використання у зарядних станціях.

Ключові слова: зарядні станції; електромобіль; електробус; з'єднувач для зарядки; інтелектуальна вимірювальна система; електролічильник.

Метрологические аспекты внедрения зарядных станций для электромобилей

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Аннотация

Электрическая мобильность является быстро развивающейся сферой, поэтому электроэнергия рассматривается как один из основных альтернативных видов топлива. Электричество является особенно привлекательным источником энергии для использования электромобилей в городских/загородных агломерациях и других густонаселенных районах. Разветвленная сеть зарядных станций для электромобилей является основным фактором использования электромобилей.

Основным методом зарядки является подключение электромобиля к источнику питания переменного тока. Альтернативным способом зарядки является подключение электромобиля к источнику питания постоянного тока. Существует три основных варианта подключения электромобиля к зарядной станции: с помощью специального кабеля питания; с помощью пантографа; беспроводное подключение. Наблюдается острая потребность в разработке национальных или региональных метрологических правил для зарядки электромобилей.

Ключевые слова: зарядные станции; электромобиль; электробус; соединитель для зарядки; интеллектуальная система измерения; электросчетчик.

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